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SANUSI, ABU CASHOPEH

AGRICULTURAL LIMESTONE DEMAND REQUIREMENTS AND SUPPLY PRODUCTION IN ALASKA

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AGRICULTURAL LIMESTONE

DEMAND REQUIREMENTS AND SUPPLY PRODUCTION

IN ALASKA

A

THESIS

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Abu Cashopeh Sanusi, B.S.

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AGRICULTURAL LIMESTONE
DEMAND REQUIREMENTS AND SUPPLY PRODUCTION
IN ALASKA

RECOMMENDED:

David R. Maneval

Carol E. Lewis

Chairman, Advisory Committee

Department Head

APPROVED:

Vice Chancellor for Research and Advanced Study

July 9, 1983
Date

ABSTRACT

The need for agricultural limestone to neutralize acidic soils and enhance plant growth in agricultural areas of the state has prompted this research project.

Based on 500,000 acres available for agricultural production between 1983 and 1992 and the average limestone requirements of 2 tons per acre, the maximum necessary will be 1,000,000 tons over 10 years.

This study identifies limestone deposits in Alaska and suggests three suitable outcrops for use as agricultural limestone. It further describes economic methods of mining, crushing and transporting the finished product to agricultural areas.

The delivered cost per ton for each of three alternatives using all outcrops is $77.68, $78.00 and $91.24. It is $81.26 per ton when production is from one outcrop. All are less than the current imported cost of $200 per ton. A simulation of cost/benefit to Alaskan farmers under various scenarios is also presented.

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INTRODUCTION

Within the last few years world food demand has been growing at a higher rate than production and it is envisioned that world population will continue to grow faster than world food production. This critical condition in world food production is sufficient justification for an aggressive agricultural development program in Alaska.

Unfortunately, from a series of studies and experiments conducted at the Agricultural Experimental Station, University of Alaska, it has been found that most Alaskan soils are acidic and must be conditioned to secure a more favorable plant growth and yield. Application of ground limestone is a common and comparatively cheap source of soil conditioner for pH control.

The need for crushed limestone for agricultural purposes in the absence of local sources and production, would require its importation into this region from other states. The physical distances involved coupled with the usual substantial time lag from order elsewhere to delivery in Alaska would result in high costs of the limestone with subsequent high costs in agricultural production.

Because of the intense public interest in agricultural development, the Department of Commerce and Economic Development has supported the investigation of possible local sources of agricultural lime near agricultural areas. The amount of crushed limestone required for soil conditioning and related agricultural uses within the next decade may justify the operation of limestone quarries in Alaska.

AGRICULTURAL LIMESTONE

USES

Limestone and dolomite are applied to soils to correct soil acidity, add calcium and magnesium, improve soil structure and maintain or promote soil conditions favorable for the utilization of soil nutrients by plants and for the growth of desirable soil organisms. Limestone or dolomite so used are referred to as "agricultural limestone", "aglime" or simply "lime". Application of agricultural limestone to the soil is called liming.

All plants can tolerate a degree of free acidity provided they are able to secure the essential nutrients. On the other hand, the degree of acidity exhibited by the soil is a measure of the difficulty with which plants secure the needed nutrients, especially calcium and magnesium (Fipping, unpublished data). Many investigations have shown that the growth and yield of crops are affected by soil pH. Strongly acid subsoils drastically reduce crop yields as compared with those obtained on the same soil where the soil profile was less acid. The unfavorable effect of a high degree of acidity in the soil on most crops is the condition that calls for the neutralization of this acid by the use of some basic material such as limestone.

Acidity in the soil is identified with that part of the solid material of the soil that has a jelly or glue-like quality known as colloids. Colloids of the soil are of two types; organic and mineral. Organic colloids result from the decomposition of organic matter. Dominant in the mineral colloids is silica, the SiO_2 equivalent of which makes up from 50% to as much as 95% of soils. Sands are richest in this and nearly all of their silica is in large granules of SiO_2 and essentially inactive. The more clayey the soil, the less the total silica content and yet the higher is the amount of the silica in the active colloidal form. Silicon dioxide (SiO_2) in combination with water forms silicic acid that forms colloids. These soil colloids have a relatively high chemical and physical reactivity due to their fineness. The chemical problems of soil fertility are those presented by the properties of these colloids.

Many agronomists agree (Hall and Free, 1979) that most crops require some lime if pH falls below 6 and that most require no lime if pH is 7 or higher. The optimal range of acidity for nearly all crops and soils is from pH 6 to pH 7, some crops being more partial to the lower limit and others to the upper limit. Below pH 5, aluminium and iron are too toxic. It has been shown, for example, that in an acid soil iron and/or manganese may enter a corn plant so freely as to clog the circulation system (Hoffer, 1926) and lead to the starvation and, ultimately, rot of the roots. Limestone, the simplest means to overcome this condition, operates to force the aluminium and iron out of solution (Bortner, 1935) and thus protect the plant. Above pH 7, (Breazeale and McGeorge, 1932) phosphate is relatively unavailable because at a high alkalinity, the phosphate is held in compounds too tightly to be absorbed by plant roots. In some cases where legumes are grown to supply nitrogen to the soil prior to raising other crops, lime is applied to raise soil pH to 6.5 or higher to accommodate the legumes. At present, nitrogen requirements for most crops are supplied from chemical fertilizers. Thus, the materials the farmer applies to the soil, such as lime and/or fertilizers, effect changes in the supply of nutrients that are beneficial to the plant. It should be noted, however, that soil acidity could be intensified by continued use of acid-forming fertilizers without a counteracting liming program. Crop yields can be improved by neutralization of subsoil acidity through mechanical incorporation of surface-applied lime with tillage equipment (Doss, Dumas and Land, 1979). Since lime moves slowly in the soil profile, it is beneficial only in the immediate vicinity of application. Thus, surface application of lime without some degree of mixing in the soil is not effective in correcting soil acidity.

At this point, it is worthy to mention that overliming is dangerous (McIntire, Shaw, Young and Robinson, 1936) and could be associated with numerous plant disorders. Overliming causes depression of the availability to the plant of iron and manganese. This results in chlorosis, a lack of chlorophyll in the plant manifested by a whitish color of plant leaves observed in tobacco, soybeans and oats. Overliming also reduces the availability of boron which results in stem crack of some plants such as celery and cauliflower.

Acid soils tend to be deflocculated and dense. Lime tends to flocculate the colloids in some soils and thus aids the soil to take on a more granular condition that improves aeration and increases the infiltration and percolation of moisture. In some other soils the effect is different. Liming causes a drier appearance of the top soil and reduces heaving in winter. Indirectly, through the increased production of plant roots and promotion of the decomposition of organic matter, the recognition of lime as beneficial to the physical properties of all soils cannot be overemphasized.

CHARACTERISTICS

The acid neutralizing value of agricultural lime is of major significance and is measured in terms of the stone's calcium carbonate equivalent (C.C.E.); also referred to as its lime content or calcium content. Pure calcium carbonate or limestone is the standard against which other liming materials are measured (Miley, 1971). Its calcium carbonate equivalent or neutralizing value has a rating of 100%. A lime which has a rating of 80% is only four-fifths as effective as pure calcium carbonate. Thus, a ton of 80% material is equal to 1,600 pounds 100% calcium carbonate. Since transportation is one of the main lime costs, the cost to the consumer increases with transportation distance. Hence, near its point of production, a lower purity lime may be as cost effective as a higher purity source shipped from a distant point.

The following table further illustrates pounds of liming material of varying calcium carbonate equivalent required to equal a ton of 100% calcium carbonate.

TABLE 1. Liming material vs. equivalent weight per ton of 100% calcium carbonate (Miley, 1971).

Classification (Liming Material)	Calcium Carbonate Equivalent (%)	Equivalent Weight Per Ton of 100% Calcium Carbonate (lbs)
Marl or Brown Mud	60-80	3333-2500
Calcitic Limestone	80-100	2500-2000
Dolomitic Limestone	100-105	2000-1905
Dolomite	109	1835
Burnt Lime	179	1117

All of these materials are effective sources of lime with varied ability to neutralize acidity. Hence, different tonnages are required to raise the pH of a given soil to the same degree. The lower the calcium carbonate equivalent, the more tonnage needed.

Although a pound of dolomitic limestone, which is a mixture of calcium carbonate and calcium magnesium carbonate, or a pound of dolomite, calcium magnesium carbonate, has the capacity to neutralize more soil acidity than the same weight of calcitic limestone or calcium carbonate, these compounds do not react as quickly with acid soils as calcitic materials.

Another important factor which determines acid-neutralizing value is particle size or fineness. This property affects the rate of reaction with the soil and the length of time that an application of lime will last. Percent calcium carbonate equivalent and fineness are related when determining overall lime quality. High magnesium material with relatively low solubility products must be ground to a finer size than more soluble calcitic material.

The speed with which a liming material reacts to neutralize acidity depends on its surface area in contact with the soil. The finer the particle size, the greater the surface exposure and contact with soil. Thus, speed in neutralizing soil acidity increases with fineness and fineness is measured by the percent of particles that will pass through a given standard size sieve or mesh. Within certain limits fineness is essential. Particles coarser than 10-mesh are very slow to enter into solution and diffuse into the soil. Materials of 60-mesh and certainly 100-mesh have been found efficient (Peele, 1936).

The measure of the commercial value of liming materials does not only depend on content of its calcium and magnesium oxides but also on its fineness. When crushed limestone is thoroughly mixed with the soil, the reaction with coarse particles is slight. Fine particles react readily and extensively. Intermediate size particles have an in between reaction rate. Hence a mixture of fine and intermediate particles is desirable for both speed and longevity. It is neither necessary nor desirable that all particles be very fine (Miley, 1971).

The relationship between limestone fineness and crop yield is illustrated in Figure 1. More than twice as much material with only 20 to 30 percent passing through 60-mesh sieve was required to produce the same yield as that containing a greater percentage of finer material. However, there was a negligible advantage of fineness exceeding about 60% of the total passing through a 60-mesh sieve, depicting the economic

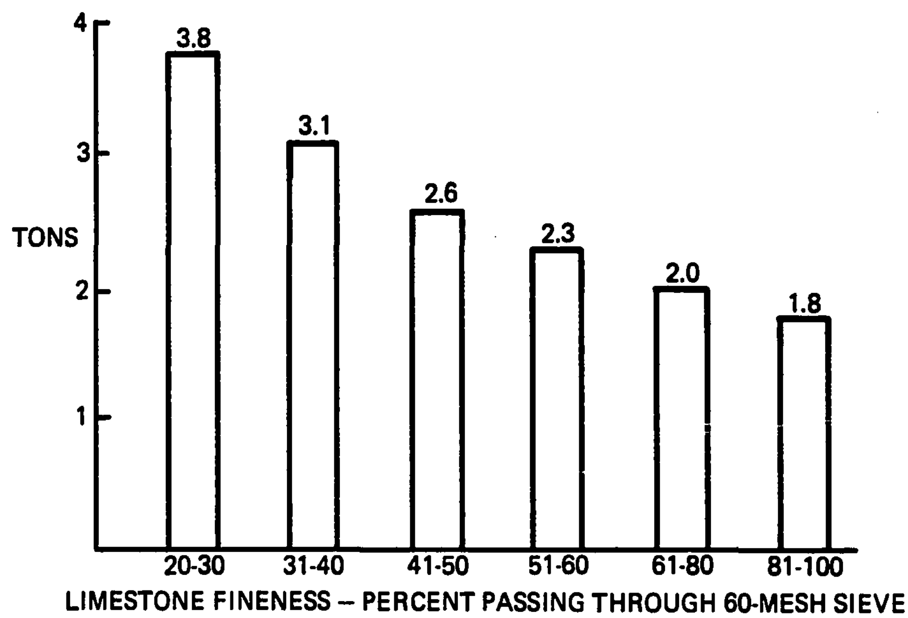

FIGURE 1. TONS REQUIRED FOR EQUAL CROP RESPONSE, (MILEY, 1971)

limit for degree of fineness relative to crop yield in this particular case. It was concluded that for limestone to be effective in readily changing the soil pH it should meet one of the following fineness specifications:

1. At least 90% should pass through a No. 10 sieve; in addition, at least 40% should pass through a No. 60 sieve.
2. At least 90% should pass through a No. 10 sieve; in addition, at least 25% should pass through a No. 100 sieve.

Generally, no standard size specifications for agricultural limestone have been recorded in the U.S.; size of particles varies from state to state. However, the Agricultural Stabilization and Conservation Committee of the United States Department of Agriculture set up the following specifications for standard agricultural limestone used in connection with its program in Illinois in 1959:

> Ground limestone containing all of the finer particles obtained in the grinding process and ground sufficiently fine so that no less than 80% will pass through a United States standard No. 8 sieve.
>
> The calcium carbonate equivalent and the percent passing through the standard No. 8 sieve must be at least 80 and one or both must be greater than 80, so that the multiplication of the percent calcium carbonate equivalent by the percent of material passing through the No. 8 sieve will be equal to or in excess of 0.72. Moisture content at the time of shipment must not exceed 8%.

In summary, correction of soil acidity by agricultural limestone is perhaps the major function of liming followed by the provision of the nutrients calcium and magnesium. Liming also aids in the regulation of the availability of part or all of other elements used by plants, repression of toxic agents, and improves the soil's physical conditions.

APPLICATION

There is a general consensus that lime can be applied to the soil during any time of the year, when weather and soil conditions permit (Remick, 1981). Because lime must be incorporated in the soil, it cannot be surface applied on frozen ground. Application should be done at not more than the optimum rate. Deviations from official recommendations could reduce the desired results and thus undermine the farmer's confidence in lime's ability to decrease soil acidity. Uniform application is also desirable. Uneven application will cause uneven growth rates and yields.

ECONOMICS OF LIME APPLICATION

Agricultural limestone is a production-cost input in the crop production process. Financial benefits induced by increasing crop yields on acid soils are widely known and well documented. Lime has therefore been called the "spark plug in the lime and fertilizer team" (Forster, 1975).

Lime is a crop production input that provides benefits at a cost. A farmer who wants to maximize net returns would increase the lime rate as long as marginal returns from increased production or decreased use of other inputs exceed the marginal cost of the lime. The decision framework for improving farm profits would therefore depend on the basic principle which explains the response of production to input levels. This may be related to the law of diminishing returns which states that "if the level of one resource is increased, while other resources are held constant, production will tend to increase at an increasing rate, then increase at a decreasing rate and finally decline." (See Appendix 1). The profit maximizing input for lime is that level of input where the returns associated with an additional unit of lime just cover the cost of the additional unit of lime.

One difficulty in applying this criterion is estimating the annual benefits of lime. A single lime application may affect soil pH for 5 years or more. Generally, use of lime is directly related to prices received by farmers for their crops. As profit-minded farmers expect higher prices for farm products, they tend to apply greater amounts of lime in order to produce higher yields from crops until the marginal benefits are exceeded. The prices of limestone and other inputs of crop production are also a factor in determining the amount of lime application. As a single application may affect soil pH and crop yield for several years, an idealistic economically optimal lime rate can be obtained by assuming that lime affects yield uniformly for a period of 5 years.

A tangible factor which could affect consumption of agricultural limestone concerns government or state programs in agriculture. The Agricultural Stabilization and Conservation Service (ASCS) in the past (Forster, 1975) had a program of sharing cost of lime purchases. While the level of participation varied over the years, the program encouraged lime use. The degree of encouragement was largely determined by farm commodities price levels. In years when commodity prices were lower than average, these programs provided an incentive for farmers to continue to purchase and apply lime. In time of high prices, these programs provided relatively little incentive for increased purchases; the net returns were more clear in times of high prices. Hence, agricultural limestone consumption is also related to cost of lime and government programs.

Example one is a four year trial in Ohio concluded in 1979 on alfalfa yield. The cost efficiency and potential return which the farmer can realize by using agricultural lime becomes apparent upon examination of yield data as shown in Table 2 below, according to Remick (1981).

TABLE 2. Total yield and return on investment

Soil pH after cropping	Lime applied in 1974 (T/A)	Yield 12% moisture hay (T/A)	Yield increase over check (T/A)	Value* of increased yield ($/A)	Cost** of lime ($/A)	ROI added return per $1 spent on aglime ($)
5.0	0	8.1	—	—	—	—
5.6	2.5	14.1	6.0	420.00	37.50	10.20
5.8	5.0	17.1	9.0	630.00	75.00	7.40
6.0	10.0	16.6	8.5	596.00	150.00	2.97

* Alfalfa @ $70/T ROI = Return on Investment

** Aglime @ $15/T

It is evident here that the total alfalfa yield in three aglime treated plots averaged twice that produced in those plots where agricultural lime was not applied. In a real situation, this added production would have represented an increased return to the farmer of from \$2.97 to \$10.20 per \$1.00 spent on aglime. In the case illustrated, the best rate of return is at 2.5 tons per acre of aglime.

Example two, shown in Table 3, is a trial in Maryland in 1975 designed to measure the effect of agricultural lime and fertilizer on corn yields.

TABLE 3. Aglime fertilizer interaction and corn yield response (Remick, 1981)

plot no.	yield (Bu/A)	value of corn @ \$2.75/Bu (\$)	fertilizer* cost (\$)	aglime cost** @ \$15/ton (3 yr period) (\$)	value over untreated plot (\$)	net return on each \$ invested (\$)
1	22.6	62.43	none used	none used	0	0
2	98.7	271.43	52.20	none used	209.00	3.00
3	47.5	130.63	none used	10.00	68.20	5.82
4	114.1	313.78	52.20	10.00	251.35	3.04

* Fertilizer cost for 1 year

** Aglime cost @ 2 tons/acre pro-rated over 3 years

These results clearly showed that agricultural lime and fertilizer increased grain production where applied individually, while each complimented the yield effect of the other when applied together.

The following three examples demonstrate results obtained from soil fertility trials in Alaska.

Table 4a indicates that: treatments receiving 2 ton/A of lime outyielded unlimed treatments by an average of 41%. Average yields per acre for the same amount of urea and ammonium nitrate with lime were 5827 and 6333 lbs, respectively (8 1/2% greater yield in the latter case).

TABLE 4(a). Dry matter yields of Weal barley as affected by lime, N rate and N source, (Mitchell, 1981).

N Rate	Dry Matter Yield* 0 Lime	2 T/A Lime
Lb/A	Lb/A	
0	210	1721
30U	2439	4043
60U	4017	5868
90U	4728	6412
120U	4994	6986
30AN	2820	4197
60AN	5562	6365
90AN	5477	6820
120AN	5387	7948

U = urea; AN = Ammonium Nitrate

* Harvested at early dough stage. All treatments received 80 lb/A P_2O_5 and 80 lb/A K_2O

TABLE 4 (b). Dry matter yields of Weal barley as affected by P rates with and without lime, Point MacKenzie, (Mitchell, 1981).

P_2O_5 Rate	Dry Matter Yield*	
	0 Lime	2 T/A Lime
Lb/A	Lb/A	
0	1153	2306
30	3653	5360
60	4352	5977
90	5667	7060
120	5897	6765

* Harvested at early dough stages. All treatments received 75 lb N/A as ammonium nitrate and 80 K_2O/A as K_2SO_4

Table 4b indicates that on both limed and unlimed soils, barley yields responded to phosphate with incremental increases up to 90 lb P_2O_5/A and were followed with a decline beyond that rate. This indicated that 90 lb/A of P_2O_5 results in the maximum yield. At 0 phosphate rate, lime application doubled yields, indicating increased availability of phosphate at higher pH level. Yields at 60 lbs/A of P_2O_5 were higher than those at 120 lbs/A of unlimed soils by about 1.4%. Averaging all P_2O_5 rates, liming increased yields by 32%.

TABLE 4(c). Effects of lime and fertilizer rate on yields of selected forages, Point MacKenzie, (Mitchell, 1981).

Forage Variety	Dry Matter Yield			
	Low Fertility		High Fertility	
	-Lime	+Lime	- Lime	+Lime
	lb/A			
Denali alfalfa	<50	98	67	115
Alaskaland new clover	168	285	369	625
Sweet clover	<50	468	<50	837
Manchar brome	482	1285	1078	2049
Engmo timothy	1024	1419	1905	2076
Annual rye grass	4140	4109	7275	6703
Weal barley	2139	4229	3710	7088
Eero barley	980	2229	1884	5122

Low fertility 40-40-30, i.e., 40 lbs/A, N - 40 lbs/A, P_2O_5 - 30 lbs/A, K_2O

High fertility 80-80-60, i.e., 80 lbs/A, N - 80 lbs/A, P_2O_5 - 80 lb/A, K_2O

+Lime - 2 tons/A

In Table 4(c) low and high fertility were enhanced by lime application. In summary, results from Tables 4a, 4b and 4c show that crops such as barley, bromegrass and forage legumes would require lime application rates of 2.0 to 2.5 T/A in such acid soils for maximum yields.

The preceding data from all examples, with special attention to those in Alaska, are self-evident. Each demonstrates that the application of agricultural lime when done on the basis of sound recommendations provided by accredited agricultural testing or experimental stations, makes excellent agronomic and economic sense.

Due to the fact that agricultural lime breaks down and reacts slowly with the soil, its effects may not appear until 1 to 2 years after application; hence crop response is usually not dramatic. However, with its capability to neutralize soil acidity, to increase the effectiveness of high cost fertilizers and to improve overall soil fertility under acidic soil conditions, it represents one of the farmers' most cost effective means of increasing the productivity and profitability of their business.

THE DEVELOPMENT OF AGRICULTURE IN ALASKA
THROUGH YEAR 2000

OVERVIEW AND LAND DISPOSAL

The State of Alaska contains about 20,000,000 acres of potential agricultural lands which are climatically and biologically able to produce adapted crops such as barley, oats, potatoes and cool-season forages successfully. As the majority of Alaskan soils with good agricultural potential have remained undeveloped, very little is known about their fertility and yield.

In the past, there has been a misconception that the Alaskan climate is unsuitable for agricultural development on a commercial basis. Although it is true that the frost-free growing season is relatively short (90-110 days), substantial plant growth and yield can be achieved during this short period. Results from rapeseed and barley variety and yield trials conducted in Fairbanks and Delta Junction indicate that Alaska has a decided advantage over most of the feed barley and northern rapeseed producing countries, in both quality and yield.

Of the 20,000,000 acres of suitable agricultural soils, the State of Alaska will have title to 24% (4.8 mill. acres); the Alaska Native Corporations 17% (3.4 mill. acres) while the balance of about 11.8 mill. acres or 59% will be retained under federal jurisdiction (Epps, 1982). Added to the 4.8 million acres of state-owned agricultural soils, of which 296,000 acres are considered climatically marginal, is an area of some 4 million acres of reindeer grazing lands on the Seward Peninsula.

Alaska's limited transportation, processing and marketing facilities have effectively reduced the total amount of state and Native land that may be considered for agricultural development by the year 2000 to 3 million acres. This estimate includes only those lands that have been or may be allocated for agriculture and are accessible in the near term. Areas with the highest agricultural potential and with the greatest probability of near term agricultural development are identified as follows:

TABLE 5. Agricultural land and ownership patterns (Epps, 1982)

Area	State Ag Potential (acres)	Alaska Native Ag Potential (acres)	Combined Ag Potential (acres)
Middle Tanana	728,000	-	728,000
Lower Tanana	877,250	168,000	1,045,250
Susitna	923,000	106,000	1,029,000
Kenai Peninsula	124,000	102,000	226,000
Total	2,652,250	376,000	3,028,250

Figures 2 and 3 show state and Native agricultural land holdings in the middle and lower Tanana and Southcentral (Susitna and Kenai Peninsula) areas respectively.

The preceding acreages represent 2.6% of the state's entitlement of 104 million acres and 0.9% of the Alaska Native Corporation land entitlement of 44 million acres, or 0.8% of Alaska's entire land base. Some

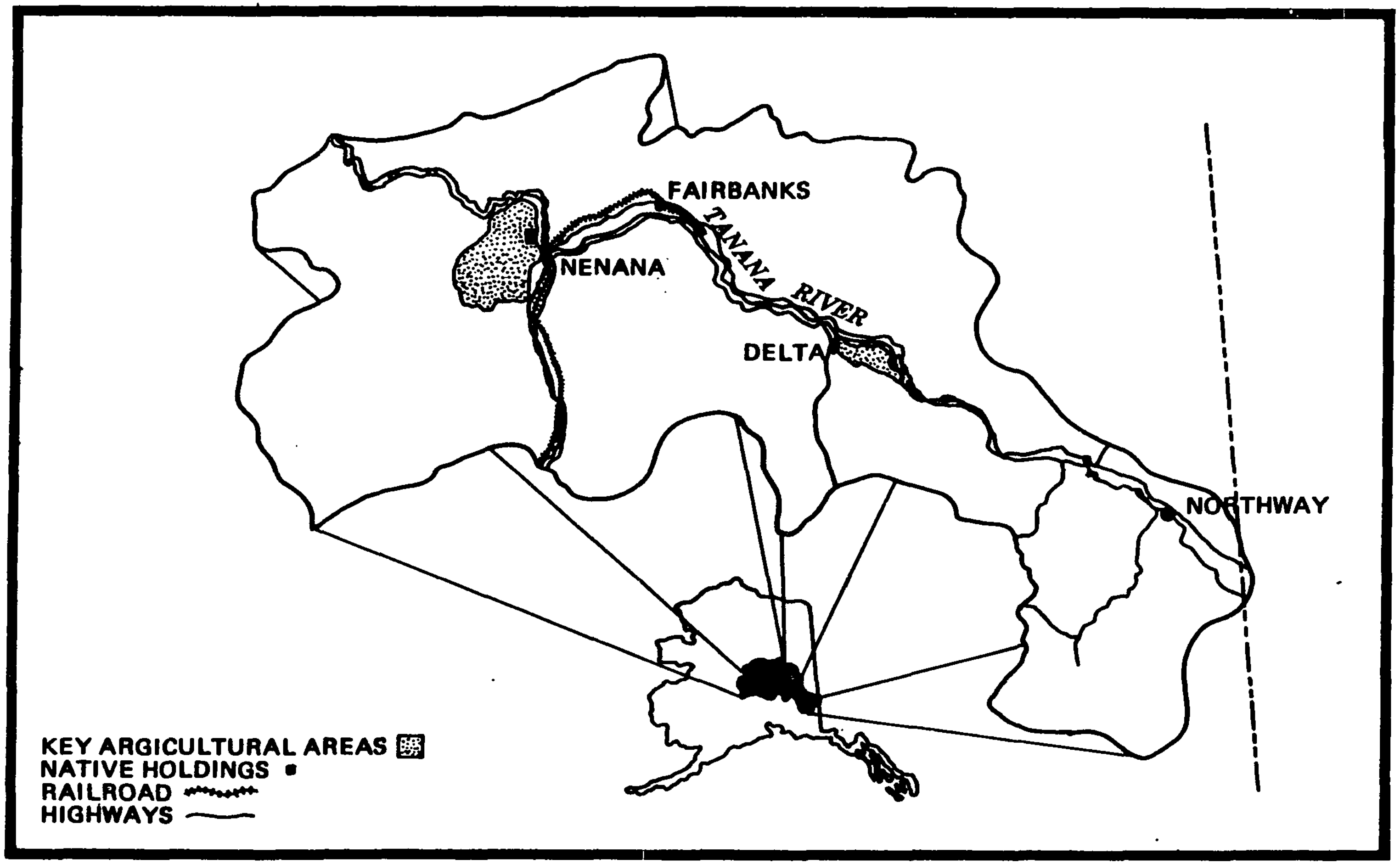

FIGURE 2. AGRICULTURAL PROJECT AREAS - MIDDLE & LOWER TANANA, (EPPS, 1982)

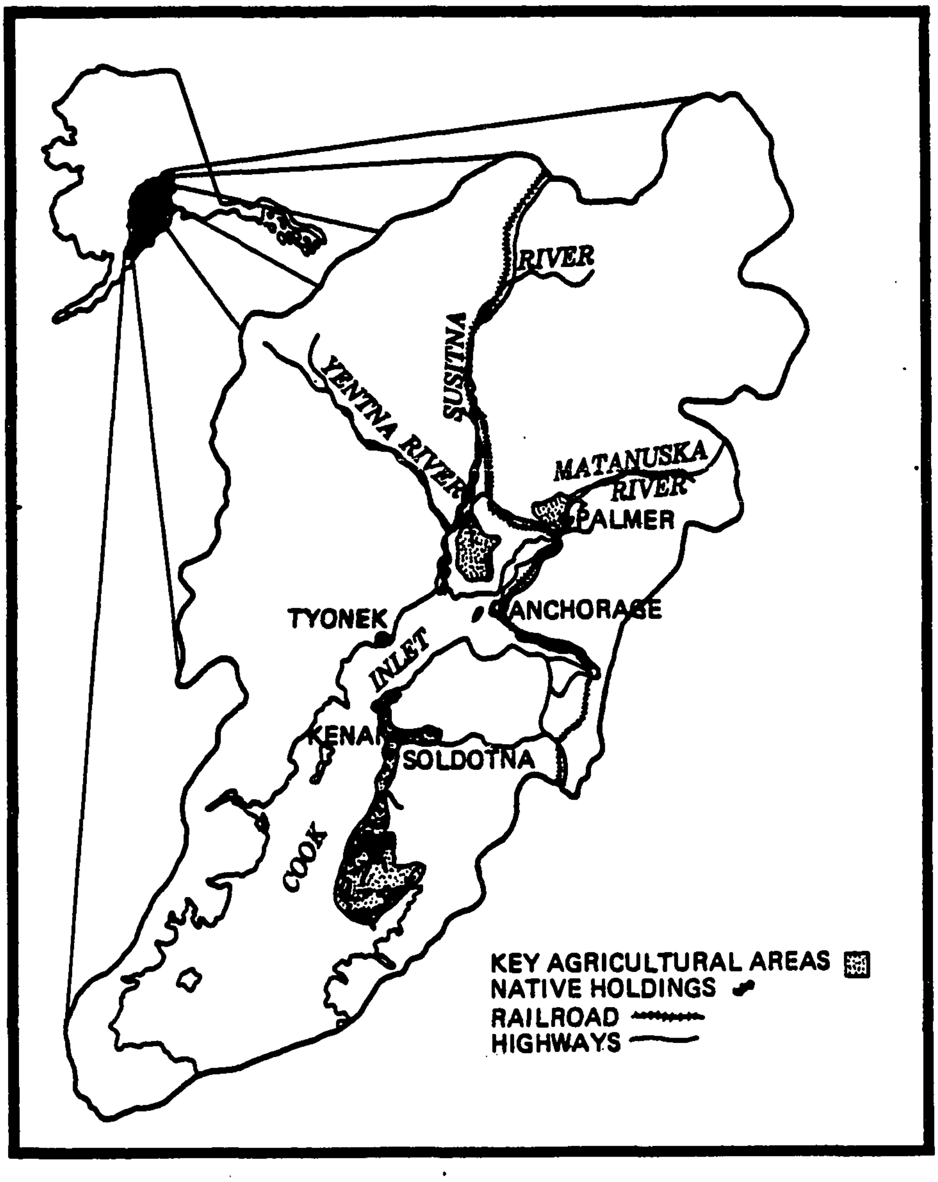

FIGURE 3. AGRICULTURAL PROJECT AREAS - SOUTH CENTRAL, (EPPS, 1982)

85,000 acres of the above acreage were designated for the development of large-scale grain type farms. Grain and rapeseed farms are projectd to range from 1,000 to 3,000 acres for a family operation. Analyses by the Agricultural Experimental Station, among others, showed that the per acre cost of production decreases as farm size increases and additional cost effectiveness could be achieved as farm size increases and the family farm constraint is eliminated. Present considerations are for family farms up to 3,000 acres in size.

In 1981, the state administration set a goal to achieve crop production from 500,000 acres by 1990. This area is considered sufficient to establish a feed-grain industry to support livestock and dairy production, and to support infrastructure such as livestock processing facilities and grain marketing systems.

By 1985, under the present plan, existing and proposed project areas would include Delta I, Delta II, Point MacKenzie, Nenana, Delta Creek and Fish Creek (see Fig. 4). Small tracts outside the agricultural project areas will also be disposed of in many areas of the rail belt. By 1992, according to the 1982 draft of the 10 Year Agricultural Development Plan, about 709,325 gross acres of agricultural land are projected to be transferred from state ownership to private ownership. Only those lands disposed of through 1985 (approximatly 339,000 acres) are assumed to be completely cleared before 1992 and capable of full production. This acreage will include both project and non-project areas. Appendix 2 illustrates the schedule for land development, clearing and production.

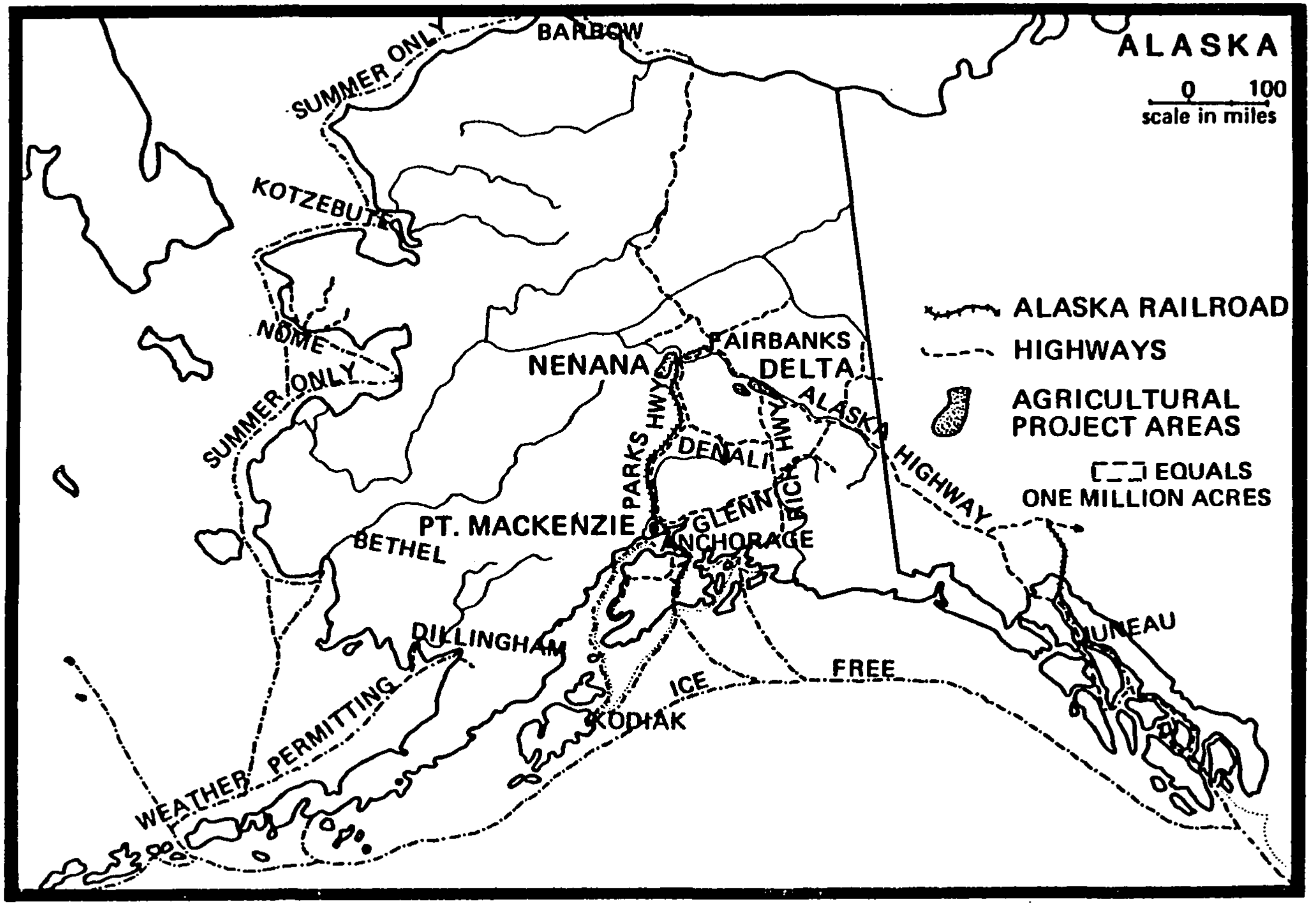

FIGURE 4. ALASKA'S THREE AGRICULTURAL DEVELOPMENT AREAS.

PUBLIC AND PRIVATE SUPPORT AND EDUCATION RESOURCES

There has, in general, been a strong support from both the private and public sectors for the development of large-scale agricultural activities in the State of Alaska. The private sector is reacting positively to opportunities created by the state thru transfer to private ownership of large tracts of state land to individuals. This creates opportunity for private individuals to own and operate farms and related businesses.

Due to the low level of federal developmental support (Lewis and Thomas, 1982) the Alaska state government has taken up a leading role by the creation of agricultural projects in some selected areas. The state, assuming this role as a primary developer of agriculture, has been able to accelerate progress in this direction through the different branches of government, which in turn have formulated development policy and plans, implemented land disposals, provided low cost financing and the establishment of a state marketing board for in-state or export sales or agricultural products.

It is worthy to mention here that agricultural development efforts have been hinged on the successful transfer of research and technology to private sector farmers. Available educational resources were therefore utilized from various areas to assist farmers in using effective techniques in land clearing, fertilizing, planting and harvesting.

The Cooperative Extension Service can assign employees to the different project areas while the Agricultural Experimental Station of the University of Alaska is engaged with research work. These state programs are supplemented by several federal programs. For example the Soil and Conservation Service of the U.S. Department of Agriculture deals with wind erosion and water problems, and the U.S. Agricultural Stabilization and Conservation Service provides farmers with information on federal programs.

PROJECT LOCATIONS

The Delta Project, located in the Tanana River Valley some 100 miles southeast of Fairbanks, was initiated in August, 1978 when about 60,000 acres of state land east of Delta Junction and north of the Alaska Highway were divided into 22 tracts and sold by lottery. The stipulation of the sale was that the land be used soly for agricultural purposes (Duffy, 1981). The state then constructed 18 miles of roadway that provides access to all 22 tracts. The tract sizes are large, averaging 2,600 acres (Thomas and Lewis, 1980). The price of land was set at a nominal fee and averaged about $51 per acre. This area was chosen due to presence of suitable soils, its proximity to a major transportation corridor, the existence of an already established small farming community in the vicinity and the availability of agronomic data for barley production in the region. A cost/benefit analysis indicated the project to be economically feasible for two crops: barley and rapeseed (Thomas and Lewis, 1979). Hence most of the existing Alaska barley crop is located in this area.

The Delta Project was regarded as a pilot project known as Delta I and an estimated $35 million has been invested for farm construction and land clearing. Production is already underway, with yields ranging from 60 to 90 bushels per acre, with an average yield of 1.15 tons per acre.

Delta II is the east extension of Delta I. The total acreage of 22,500 is divided into 15 tracts. Delta Creek is a further extension of the project area to the west of Delta I. Total project acreage for Delta Creek is projected at 36,000.

The Nenana-Tolchaket Project, a few miles west of Nenana, includes about 135,000 acres of land with excellent agricultural potential. The project is located at the confluence of the Nenana and Tanana Rivers and is 60 miles south of Fairbanks. The area is served by the George Parks Highway linking Fairbanks and Anchorage and by the Alaska Railroad.

The growing season in the Nenana area is longer than in the Delta area due to its lower elevation (400 feet). This factor, combined with the access to highway, railroad and river barge transportation, propagates hopes that this project may become the center of Alaska's most productive agricultural area.

The Point MacKenzie Project is situated on about 15,000 acres of land across Knik Arm from Anchorage in the lower Susitna Valley. A 12-mile extension of the Goose Bay Road was partially completed in December, 1980. This connects with a 15-mile road extending to all tracts in the project. The latter was built between November 1980 and January 1981. In September 1982, 29 parcels were disposed in this project, 17 of which are to be developed as dairy land. Land clearing commenced in the fall of 1982.

Fish Creek area, now designated as an agricultural area, is part of the Point MacKenzie Project. Total acreage of about 21,000 is still under state ownership. Planning for disposal is in progress.

Non-project areas account for about 48,000 acres and are located in various sections of the railbelt. Disposal is scheduled through 1985. Additional areas, amounting to 25,000 acres, are being considered for future disposal.

DEMAND FOR AGRICULTURAL LIMESTONE ASSUMING MOST PROBABLE AGRICULTURAL DEVELOPMENT IN ALASKA

In the Delta Project, soil pH values range from 5.7 to 6.5. Adjustment of pH in this area for enhanced growth of crops, such as barley, should be between 6.8 and 7.0. Soils would require lime ranging from 2,000 lbs to 5,000 lbs per acre. An average of 3,000 lbs per acre has been accepted as a realistic estimate (Wooding, 1976).

Point MacKenzie soils are more acidic than those at Delta. Preplant soil analyses showed a pH of 5.0 to 5.3. Lime applications here for near ideal conditions have been estimated at an average of 4000 lbs per acre (Mitchell, 1981).

No lime application figures are available for the Nenana-Tolchaket Project. However, it is speculated that this area may not require as much liming as either of the other two projects. As a result, in the estimation of the total lime demand for all projects, the maximum of 4000 lbs per acre has been estimated as a reasonable requirement for the average demand.

From the existing agricultural lands and disposal schedule, the following acreages would be cleared and available for production by 1992:

Existing land prior to state agricultural disposals	- 20,325 acres
Delta I	- 60,000 acres
New Land (Project)	- 219,000 acres
New Land (Non-project) - 90% of 48,000	- 43,200 acres
Total	342,525 acres

The 342,525 acres are a tentative estimate of the minimum with high possibilities of attaining the original target of about 500,000 acres (Armstrup, 1983) within 10 years, i.e., an addition of 90,000 acres (90% of 100,00) at Susitna and 67,500 acres (90% of 75,000) at Kantishna by 1992. For the purpose of this study, it will be assumed that the maximum attainable of about 500,000 acres would be cleared and made available for production by 1992.

Demand for agricultural limestone, assuming optimal soil conditioning practices for the period under consideration, at 2 tons or 4000 lbs per acre would be 1,000,000 tons. On a broadly based assumption that liming is evenly done over the period of 10 years, then annual demand would be 100,000 tons. Estimation, for mine production purposes, of demand requirements for each area is categorized and estimated as follows:

Delta Area:

Delta I	- 60,000	acres
Delta II	- 22,500	acres
Delta Creek	- 36,000	acres
90% of (63,525 acres) Non-project Areas	- 57,172.5	acres
TOTAL	175,672.5	acres

Total demand for the 10-year period is 351,345 tons or 35,135 tons (17,026 cu yd) per year.

Nenana Area:

Nenana I		- 45,000 acres
Nenana II		- 45,000 acres
Nenana III		- 45,000 acres
Kantishna		- 67,500 acres
	TOTAL	202,500 acres

Total demand for the 10-year period is 405,000 tons or 40,500 tons (31,154 cu yd) per year.

Point MacKenzie Area:

Point MacKenzie		- 11,700	acres
Fish Creek		- 13,800	acres
10% of (63,525) Non-project Areas		- 6,353	acres
Susitna		- 90,000	acres
	TOTAL	121,853	

Total demand requirements for the same period is 243,705 tons or 24,371 tons (18,747 cu yd) per year.

The combined demand requirement for all areas is approximately 100,000 tons per year.

POSSIBLE SOURCES OF SUPPLY IN ALASKA

The Paleozoic formations in Alaska, as commonly found elsewhere in the United States, are characterized by widespread occurrence of limestone and dolomite. Deposits of limestone are known in many parts of the State of Alaska, the most extensive being in the islands of southeastern Alaska and the adjacent mainland (see Figure 5). Spot sampling of rock exposures, geologic reconnaissance and laboratory tests have shown sources of high calcium limestone in many areas, pure enough to be used in the production of portland cement and for agricultural purposes. Most of these may not be economically and commercially viable at present, due to the lack of adequate transportation facilities and a market. Despite the scattered occurrences of these deposits, 58 localities were examined in the past, and 8 were opened as quarries during the late 1920's to mid-1940's. A quarry of the Pacific Coast Cement Company was operated on Dall Island. Limestone was also shipped to the Pacific coast states by both the Newmont Marble company and the Alaska Marble Company. For the purpose of this investigation of agricultural limestone, a key requirement for a satisfactory source is distance of the source from agricultural production areas, as transportation cost will be a major factor. Thus, the closer the source to the agricultural area, the more economically feasible the use of the limestone would be.

A summary of the major known deposits is provided for comparison purposes (see Table 6) and is followed by brief discussions on each.

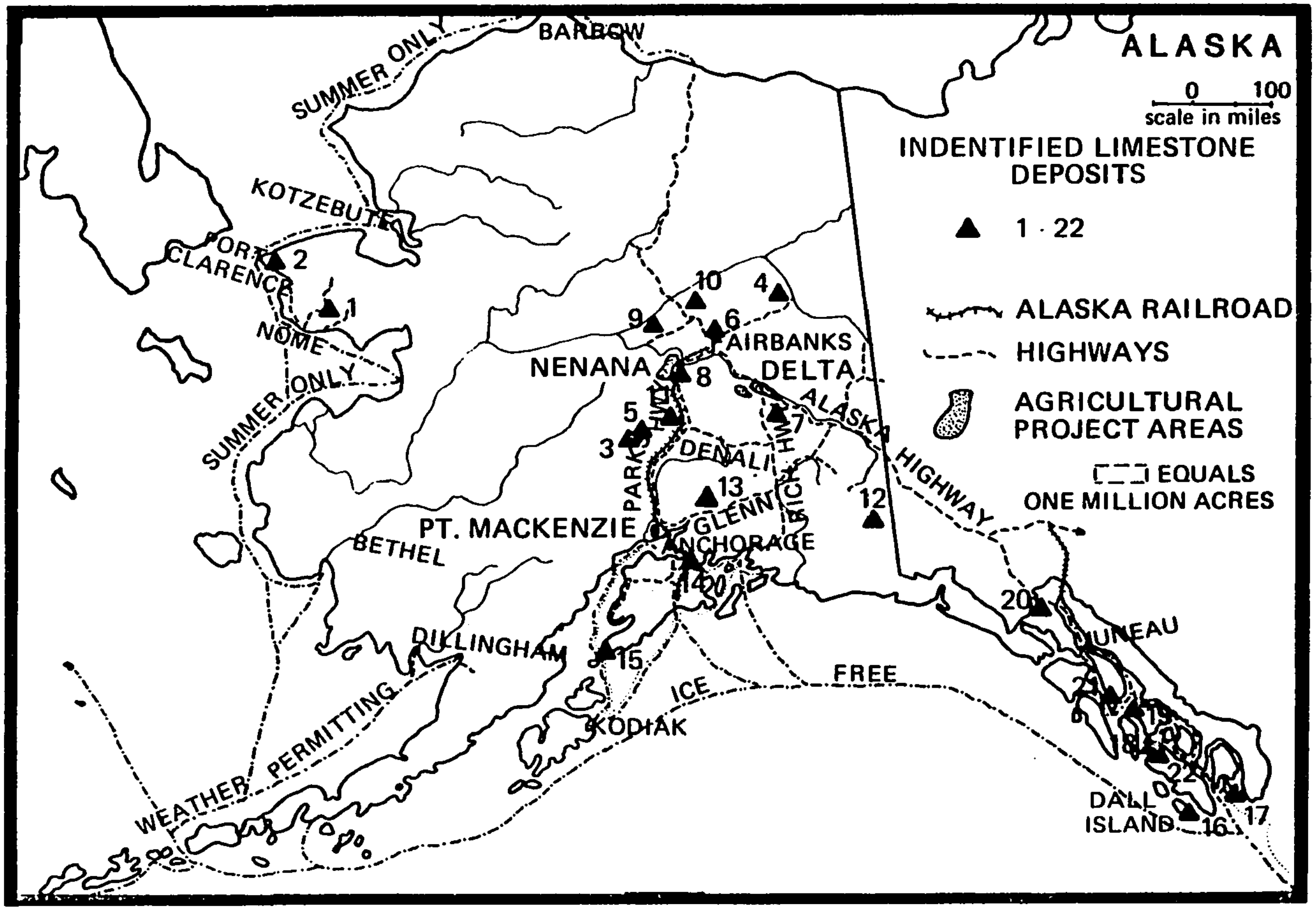

FIGURE 5. ALASKA'S AGRICULTURAL DEVELOPMENT AREAS AND TRANSPORTATION SYSTEMS RELATIVE TO IDENTIFIED LIMESTONE DEPOSITS.

TABLE 6. Summary of identified limestone deposits in Alaska

Name	Location	Mean % $CaCO_3$	Estimated Reserves (mil. tons)	Comments
		Western Region		
1) Mount Distin	Nome Area	N.A.	N.A.	Thickness ranges from 2,200 ft. to 3,200 ft. and of high purity. Further field work required.
2) Port Clarence	Lost River area Seward Peninsula	N.A.	N.A.	Several thousand feet thick with sequences of black limestone 500 to 1,000 thick exposed east of Lost River.
		Interior Region		
3) Chulitna River	West and southwest of Golden Zone mine	88.0	103	Two deposits at the heads of Long and Copeland Creeks. Easily accessible.
4) Crazy Mountains	Crazy Mts., 20 miles from Steese Highway	N.A.	N.A.	Easily accessible but further field work required.
5) Foggy Pass	15 miles northwest of Cantwell at the entrance of Foggy Pass	89.0	100	Very close to McKinley Park. Consists of grey crystallized, folded and contorted limestone.
6) Fox	3/4 mile southwest of Fox	53.0	N.A.	Easily accessible. Too small for commercial development.
7) Hoo Doos	East of Isabel Pass	94.0	300	Highly fractured. Easily accessible.

TABLE 6. Summary of identified limestone deposits in Alaska (continued)

	Name	Location	Mean % $CaCO_3$	Estimated Reserves (mil. tons)	Comments
8)	Nenana	Birch Creek Schist	95.0	N.A.	A blue-grey lens, 1 to 4 ft. thick and 400 ft. long. Too small for commercial development.
9)	Rampart	15 miles north of Manley Hot Springs, North Fork of Baker Creek	90.0	N.A.	Easily accessible. Further exploration work needed.
10)	Tolovana	40 miles northwest of Fairbanks, Minto Flats-Dugan Hills	99.0	N.A.	A very large deposit which needs evaluation.
11)	Windy Creek	Windy Creek	92.0	180	Easily accessible and approximately 4 miles from Cantwell.
			Southcentral Region		
12)	Chitistone & Nizina	Wrangell Mtns.	N.A.	N.A.	Sporadically distributed along the southern flank of the Wrangell Mountains. Very little is known.
13)	Kings River	Matanuska Valley, Kings River drainage. North of Glenn Highway	97.0	33	Consists of several large steeply dipping masses.
14)	Potter	1/2 mile northeast of Potter	96.0	N.A.	Consists of several lenses. Needs further exploration work.

TABLE 6. Summary of identified limestone deposits in Alaska (continued)

	Name	Location	Mean % $CaCO_3$	Estimated Reserves (mil. tons)	Comments
15)	Seldovia	Seldovia, Kenai Peninsula	89.0	0.2	Transportation limited to barge.
			Southeast Region		
16)	Dall & Long Island	Waterfall Bay and Gleva Bay	95.0	200	Massive and extensively folded. Accessibility almost impossible.
17)	Glacier Bay	Willoughby, north & south Marble Islands	97.0	N.A.	Accessible with difficulties.
18)	Heceta-Tuxekan	Heceta and Tuxekan Islands	94	N.A.	High purity, massive and thickness extremely variable.
19)	Mud Bay	Northwest Shrubby Island	N.A.	15	Exposed as a 1500 foot beach outcrop.
20)	Pleasant Camp	Haines cut-off international boundary	N.A.	N.A.	Further field work required.
21)	Saginaw Bay	Kuiu Island	N.A.	N.A.	Needs further exploration.
22)	San Alberto Bay	Wadleigh Island	N.A.	40	Accessible by waterway.

NOTE: N.A. - not available

Western Region

Mount Distin Limestone:

This deposit outcrops in the Nome area between the upper Nome River and ridges south of Salmon Lake (Moffit, 1907; Eberlein, 1961). Stratigraphically its thickness ranges from 2,200 feet to more than 3,200 feet. It is a compact and thick bedded formation with some micaceous layers. However, zones at least several hundred feet thick are free of such interbeds. The limestone deposit appears to be very clean and of high purity. Further field work is necessary for a complete geologic interpretation.

Port Clarence Limestone:

This occurrence is located in the Lost River area, Seward Peninsula. The limestone is fragmentary and up to several thousand feet thick. It contains interbedded argillaceous limestone and thin bedded limestone. Several thick sequences of black limestone aggregate 500 to 1,000 feet are exposed east of the Lost River (Knopf, 1908; Eberlein, 1961).

Although no chemical data are available, it is recorded that the black phase of the limestone is nearly pure calcium carbonate.

Interior Region

Chulitna River Limestone:

There are two principal limestone deposits in this area, which lie at the heads of Long and Copeland Creeks and west and southwest respectively of the Golden Zone Mine (Rutledge, Thorne, Kerns and Mulligan, 1953).

The prominent outcrops are extremely fractured and weathered.

A total of 18 samples were taken from this area, which revealed the following analysis:

TABLE 7. Chemical analysis, Chulitna River limestone occurrence (Rutledge, Thorne, Kerns & Mulligan, 1953)

Sample No.	CaO	Percent $CaCO_3$ Equiv.	MgO	SiO_2
173	54.0	96.1	1.1	1.1
174	53.8	95.7	0.6	2.7
175	54.5	97.0	0.6	1.5
176	54.4	96.8	0.3	1.7
177	46.4	82.6	0.9	10.0
178	52.4	93.2	0.7	2.6
179	53.4	95.0	0.6	2.6
180	53.5	95.2	0.5	2.4
181	52.6	93.6	0.7	3.2
182	51.6	91.8	0.8	3.5
185	50.8	90.4	0.01	5.9
186	53.0	94.3	0.1	3.7
187	48.2	85.8	0.1	10.8
188	37.6	66.9	0.1	22.8
189	47.0	83.6	0.1	10.4
190	50.6	90.0	0.1	7.2
191	41.0	73.0	0.1	19.0
192 (foot-wall)	31.0	55.2	0.6	26.0

No drilling has been done, but the surface continuity of the limestone beds and attitude indicated that they will persist at depth. Total reserves are estimated at some 102.5 million tons.

Crazy Mountain Limestone:

This consists of a band of limestone which outcrops over several miles near the center of the Crazy Mountains, within 10 to 20 miles of the Steese Highway and 90 miles from the railroad at Fairbanks (Alaskan

Resource Sciences Corporation, 1976). It is believed to be homogeneous and very large.

Foggy Pass Limestone:

This is located near the headwaters of the west fork of Windy Creek at the entrance of Foggy Pass. It is about 15 miles northwest of Cantwell, near the Alaska Railroad, and 200 miles from Big Delta.

The limestone here forms a steep northwest-trending ridge that is bisected by the west fork of Windy Creek. It is exposed from the east of the West Fork to the head of the Bull River (Wolff, 1979).

As part of a series of metamorphosed sedimentary rocks, composed of shale, argillite, conglomerate, limestone, slate and quartzite, the outcrop in question consists of grey crystallized folded and contorted limestone. The outcrop width along the west fork of Windy Creek is approximately 300 feet, with an east-west strike, dipping 40^{o} to 80^{o} south.

The following table shows the results of sample analysis:

TABLE 8. Chemical analysis, Foggy Pass limestone occurrence (Rutledge, Thorne, Kerns and Mulligan, 1953)

Sample No.	CaO	Percent $CaCO_3$ Equiv.	MgO	SiO_2
163	51.4	91.5	0.35	4.1
164	47.1	83.8	0.75	7.7
165	49.8	88.6	0.25	5.9
166	50.3	89.5	0.65	5.4
167	51.4	91.5	0.40	4.0

Fox Limestone:

A small lens of limestone occurs in the Birch Creek Schist at the base of a hillside about three-quarters of a mile southwest of Fox and 10 miles north of Fairbanks (Conwell and Eakins, 1976). The outcrop, which lies along the base of the slope, is on the right limit of Gilmore Creek just above its confluence with Goldstream Creek. This lens of limestone is about 15 feet thick and can be traced for over 300 feet along the base of the hill. It strikes on an east-west direction, dipping 35°W into the hill. Analysis, across the outcrop indicated an average of 53.2% $CaCO_3$. A single sample analysis does not give a true representative picture.

Hoo Doos Limestone:

This occurrence lies just east of Isabel Pass and approximately 60 miles south of Big Delta (Wolff, 1979). By far the largest limestone resources for aglime production and nearest to the Delta agricultural areas, the area appears to contain several units of considerable size. Reserves are estimated at 300 million tons. Chemical analysis from samples reveal the following results:

TABLE 9. Chemical analysis, Hoo Doos limestone occurrence

Sample No.	Percent $CaCO_3$ Equiv.	$MgCO_3$	Fe_2O_3	SiO_2
81HD 1027	80.5	17.3	0.47	1.66
81HD 1028	97.5	1.11	0.31	0.59
81HD 1029	97.2	2.12	0.14	0.71
81HD 1030	96.9	0.97	0.16	1.99
81HD 1031	95.3	1.41	0.82	2.30

Nenana Limestone:

This is a lens of blue-grey limestone, about 400 feet long, 1 foot to 4 feet thick and is enclosed in the Birch Creek Schist. It is exposed at mile 414.5 of the Alaska Railroad cut on the north side of the Tanana River. The limestone grades laterally into more siliceous schist. Small lenses of white calcareous rock in the schist are also observed at miles 416.5 and 416.9 and at other places, but none of these bodies is large enough to be of commercial importance (Detterman, 1969).

Analysis of the limestone shows about 53.6% CaO or 95.4% $CaCO_3$ and a very low magnesia content.

Rampart Limestone:

This area lies in the Tanana quadrangle, about 145 air miles northwest of Fairbanks and 15 miles north of Manley Hot Springs. It covers a belt about 4 miles wide and 15 miles long northeast of the North Fork of Baker Creek between Roughtop Mountain and Baldry Mountain (Thomas, 1965).

It is somewhat remote but access to the area from Fairbanks is by the Steese and Elliot Highways to Eureka, a distance of 145 miles and then across country by foot trail for about 18 miles. It is about 258 miles from Big Delta.

The deposit is exposed intermittently over an extensive area. Chemical analyses of a few samples obtained are as follows:

TABLE 10. Chemical analysis, Rampart limestone occurrence (Thomas, 1961)

Sample No.	CaO	Percent $CaCO_3$ Equiv.	MgO	SiO_2
1	53.56	95.3	0.15	2.66
2	52.36	93.2	0.13	4.26
3	47.90	82.2	4.56	3.30
4	52.90	94.1	1.08	1.76
5	47.80	85.1	5.97	1.68

It is worthy to note that initial work was carried out here to determine the deposit's suitability for portland cement production for use in the proposed Rampart Dam Project. Further work is needed for a complete assessment of this potential resource.

Tolovana Limestone:

This occurs in the Minto Flats - Dugan Hills area, about 40 miles northwest of Fairbanks, 144 miles from Big Delta via Elliot Highway.

It is a highly fractured and recrystallized siliceous dolomitic limestone and is exposed continuously on the ridge between the Tolovana and Tatalina Rivers in the northeast corner of Minto Flats. The beds are massive and dip 60° to 80° southward. Two cross sections across the ridge showed a minimum thickness of at least 1,500 feet and a maximum of about 3,000 feet, reported Eberlein (1961).

In the Dugan Hills, two parallel limestone units are present in the western half of the hills, but only one occurs in the eastern half. The beds are massive and steeply dipping. The outcrop width is approximately 1,000 feet and total thickness could be much greater.

There are no chemical analyses of the Tolovana limestone, but x-ray analyses (Eberlain, 1961) of seven samples over a strike length of about 6 miles and from the bottom to the top showed no dolomite. The limestone appears to contain as much as 99% calcite. The entire formation is apparently a near pure calcite formation.

Further work could be done to determine the reserves and quality of this deposit, which may prove a useful source of limestone for future agricultural development in the Fairbanks area.

Windy Creek Limestone:

Two deposits which are about 7 miles and 11 miles respectively west of the Alaska Railroad (milepost 325) are located on the Windy Creek. A third deposit of larger size, but comparatively of an inferior quality, lies one mile west of the railroad (Wolff, 1979). Despite its poorer quality, the latter is quite suitable for agricultural use. The deposit is about 4 miles from Cantwell and about 170 miles from Big Delta. One hundred and thirty miles of this distance are traversed by the Alaska Railroad. Average thickness is 800 feet and total reserves are estimated at 180 million tons. The deposits are easily accessible.

From extensive investigations done by the U.S.G.S. and the U.S. Bureau of Mines, the Windy Creek limestone was proved to contain limestone of erratic and often high magnesian content. The following results have been obtained from chemical analysis:

TABLE 11. Chemical analysis, Windy Creek limestone occurrence (Rutledge, Thorne, Kerns and Mulligan, 1953)

Sample No.	CaO	Percent $CaCO_3$ Equiv.	MgO	SiO_2
0-5	51.9	92.4	2.10	1.9
5-10	51.6	91.8	2.45	1.5
10-15	52.9	94.1	1.50	0.9
15-20	53.9	96.0	0.80	1.0
20-25	51.2	91.1	2.50	1.8
25-30	52.0	92.5	2.35	1.0
30-35	49.7	88.4	4.55	0.8

Southcentral Region

Chitistone and Nizina Limestones:

These are sporadically distributed along the southern flank of the Wrangle Mountains near the Nizina and Chitistone Rivers. The formation lies in an east-west belt that is about 65 miles long and 14 miles wide (Eberlein, 1961). Very little is known about these deposits.

Kings River Limestone:

This deposit lies along the north side of the Matanuska Valley in the drainage of Kings River, north of Castle Mountain and about 12 miles north of the Glenn Highway and some 275 miles from Big Delta by road.

It consists of several large, steeply dipping masses of high calcium limestone in contact with granitic rocks (Conwell and Eakins, 1976). They are light colored and locally contain chert and argillite. Individual units are estimated to be up to 200 feet thick of nearly pure calcium carbonate ($CaCO_3$). A single limestone mass covers approximately 80 acres.

The following table (Jasper and Mihelich, 1961) shows results of some chemical analyses:

TABLE 12. Chemical analysis, Kings River limestone occurrence

Sample No.	CaO	Percent $CaCO_3$ Equiv.	MgO	SiO_2
12278	52.9	94	0.08	2.16
12279	54.6	97.2	0.11	1.89
12280	55.5	98.8	0.17	0.57
12281	54.5	97	0.16	0.64
12282	55.1	98	0.13	1.17
12283	55.1	98	0.25	0.81

These high grade masses are believed to be of considerable magnitude and a good source of supply for all foreseeable demands. No data are available on the total tonnage, but the general inference is that many represent almost inexhaustible reserves of nearly pure calcium carbonate suitable for almost any use—agriculture, production of portland cement with minimum reserves estimated at 33.1 million tons.

Potter Limestone:

This is a prominent ledge of limestone which lies half a mile northeast of the railroad, near Potter, and 14 miles south of Anchorage at the edge of a marsh land bordering Turnagain Arm (Burchard, 1920).

The deposit is about 20 feet thick, rises 25 feet above the marsh land and projects out about 50 feet from the hillside for some distance. It consists of lenses of pure limestone indicating 96.56% $CaCO_3$, 1.01% $MgCO_3$ and 0.76% SiO_2.

Quarrying below the marsh level could be considerably hindered by ground water. Nonetheless, in the late 1920's a few tons of rock were quarried and burnt to lime in a kiln on site. The lime was used for plastering in Anchorage reported Detterman (1969).

Seldovia Limestone:

The Seldovia limestone deposit lies 16 miles southwest of Homer at Seldovia near the tip of the Kenai Peninsula (Rutledge, Thorne, Kerns and Mulligan, 1953). The face of the 60-foot high cliff forming the point on the east side of the entrance of Seldovia Bay is composed entirely of limestone which is accessible to Cook Inlet by water. The deposit is a massive grey to white crystalline limestone.

Analysis of two samples gave the following results:

TABLE 13. Chemical analysis, Seldovia limestone occurrence (Rutledge, Thorne, Kerns and Mulligan, 1953)

		Percent		
Sample No.	CaO	$CaCO_3$ Equiv.	MgO	SiO_2
75	50.4	89.7	5.0	0.6
76	49.4	87.9	5.6	0.9

During the early years of this century, interests were shown on the deposit as a source of limestone for cement or agriculture. No production was made.

Southeast Region

Dall and Long Island Areas:

The limestone and marble deposits in these islands are massive, extensively folded, faulted and fractured and contain many mafic dykes of various spacing and size (Eberlein, 1961). The greatest thicknesses of limestone appear to occur west of Rose Inlet and southwest of the head of View Cove.

Chemical analyses indicate that the occurrence contains $CaCO_3$. The principal mineral is calcite, with up to 10% dolomite.

Maximum relief in these areas ranges from 2,000 feet to 2,500 feet. As access to the higher areas is almost impossible, exploitation by tunnelling from points near the shoreline at Rose Inlet, Waterfall Bay, may be the only approach to exploration. At Waterfall Bay, Dall Island, a beach outcrop of 12,000 feet in length and 2,000 feet in thickness was estimated at 200 million tons within a 1 mile radius and gave the following analysis (Roehm, 1946).

TABLE 14(a). Chemical analysis, Dall Island occurrence

Sample No.	CaO	Percent $CaCO_3$ Equiv.	$MgCO_3$	SiO_2
1	54.4	96.8	2.6	1.24
2	50.2	89.7	9.7	4.6
3	51.3	91.6	6.2	2.95
4	53.8	96.1	1.9	0.9
5	53.8	96.0	2.26	1.08

Two samples from Cleva Bay, Long Island, also gave the following results:

TABLE 14(b). Chemical analysis, Long Island occurrence

Sample No.	CaO	Percent $CaCO_3$ Equiv.	$MgCO_3$	SiO_2
1	53.8	96.0	2.46	1.17
2	54.8	97.8	1.00	0.48

Glacier Bay Limestone:

The deposits here at the Willoughby Island and north and south Marble Island are almost entirely composed of marble (Eberlein, 1961). A few analyses of samples from Willoughby Island indicate that it contains between 97 and 99% $CaCO_3$. These samples were collected on the southeast shore of the island where ridges rise abruptly to a height of several hundred feet, reaching an altitude of more than 1,000 feet. There is no overburden.

The largest occurrences of limestone on the mainland are south of Sandy Cove. Chapin (1920) reported that chemical analyses of the mottled marble south of Sandy Cove indicate 96.16% $CaCO_3$, 0.89% $MgCO_3$ and 2.56% insoluble residue. Other analysis in the vicinity of Sandy Cove showed between 96 and 98.5% $CaCO_3$.

Heceta-Tuxekan Islands Limestone:

High calcium limestone underlies most of Heceta and Tuxekan Islands. The limestone is typically massive and for the most part probably contains in excess of 95% $CaCO_3$ (Eberlein, 1961). The stratigraphic thickness is extremely variable. The thickest known section is on Western Heceta Island where a minimum thickness of 15,800 feet has been observed. About 2 miles east of Warm Chuck Inlet, the formation is about 9,500 feet thick. Approximately 8,700 feet of limestone is exposed on the south half of Tuxekan Island.

The same limestone beds crop out on adjacent Prince of Wales Island and on Kosciusko Island to the north across Sea Otter Sound. Very little is known of the geology of Kosciusko Island, but it is known that the limestone at Edna Bay was extensively drilled and sampled by Alcoa in 1946 and 1947. It is believed, however, that the deposit here contains a very high percentage of $CaCO_3$, e.g., samples from Port Alice indicated an average 93.34% $CaCO_3$.

Mud Bay Limestone:

The deposit is located at Mud Bay, northwest corner of Shrubby Island. The limestone is exposed at a 1,500 foot beach outcrop forming a low bluff. Estimated tonnage is 15 million. Analyses indicated a high calcium carbonate deposit (Beasley, Haring and Miller, 1965).

Pleasant Camp Limestone:

This limestone deposit occurs in the upper Lynn Canal area at mile 41 on the Haines cut-off on the Alaskan side of the international boundary. Thick beds of massive white limestone outcrop adjacent to the highway and in steep bluffs above road level (Beasley, Haring and Miller, 1965).

Analyses of two samples indicated an average of 2.28% magnesia.

Saginaw Bay Limestone:

The deposit is located in Kuiu Islands opposite Halleck Harbor. It is exposed as 1,500 foot beach outcrop with a 1,000 foot thickness (Beasley, Haring and Miller, 1965). The chemical and physical properties of the deposit suggest possibilities for a cement industry.

San Alberto Bay Limestone:

Located in San Alberto Bay, opposite Klawak, on the upper west coast of Prince of Wales Island is the San Alberto limestone.

It has an estimated thickness of 600 feet and is continuous for 2 miles. Estimated tonnage is about 40 million tons above mean sea level. It is a chemically pure lime rock (Beasley, Haring and Miller, 1965).

Three of the 22 identified deposits are considered suitable and as possible sources of supply for the agricultural areas. Viz: the Hoo Doos, Windy Creek and Kings River with mean percent calcium carbonate equivalent of 93.5, 92.3 and 97.2 respectively. See Figure 5a—Selected limestone deposits.

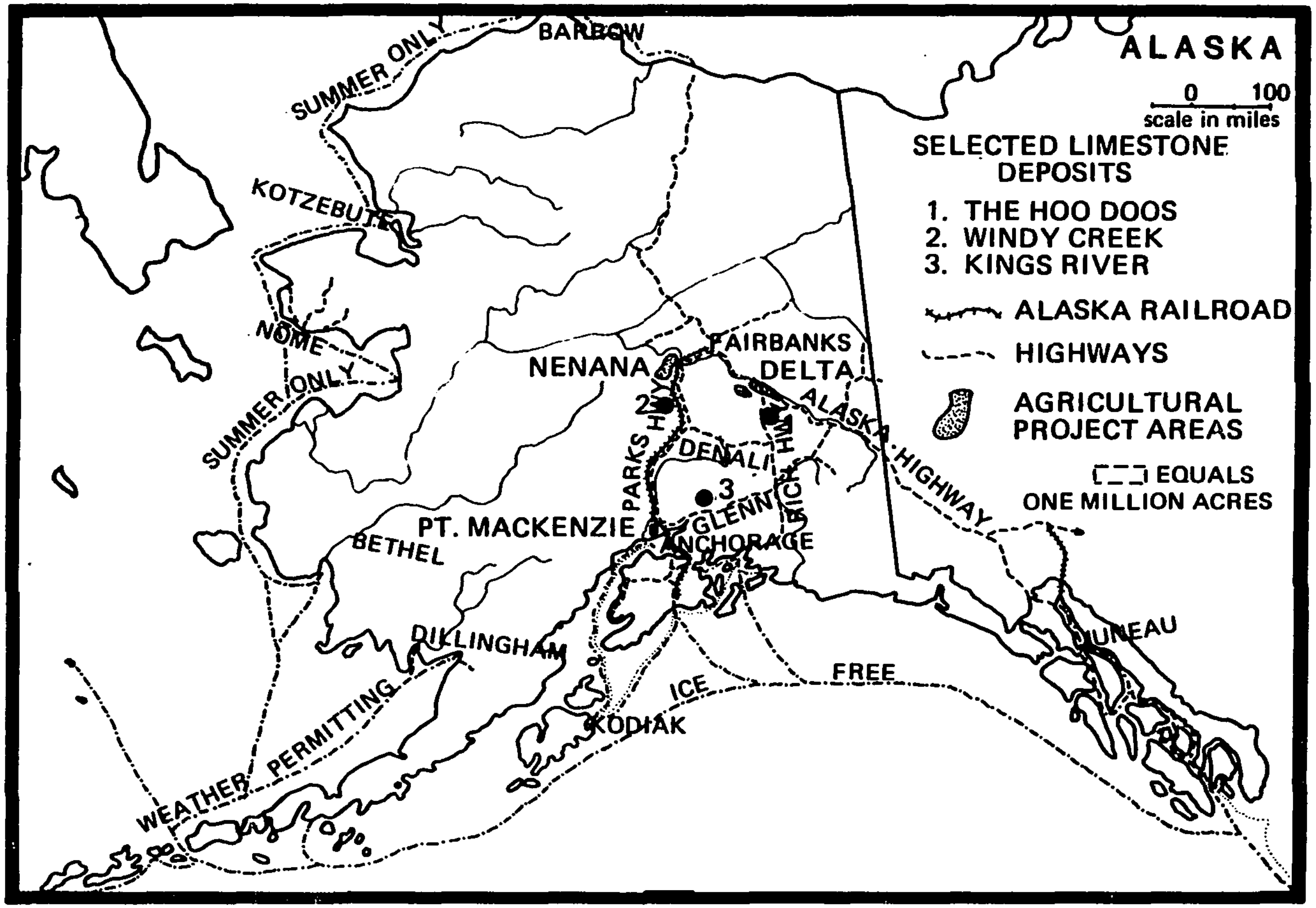

FIGURE 5(a). ALASKA'S AGRICULTURAL DEVELOPMENT AREAS AND TRANSPORTATION SYSTEMS RELATIVE TO SELECTED LIMESTONE DEPOSITS

ECONOMIC EVALUATION

This section discusses the economic feasibility of producing crushed limestone to the three agricultural areas recommended in the previous section, i.e., the Hoo Doos, Windy Creek and Kings River deposits.

Selection of these deposits is based on proximity to the agricultural areas, available reserves and quality. Besides the Windy Creek, no drilling has been done in either of the other two selected, but regularly spaced, measured outcrops are sufficient for reserve estimation. Despite the lack of subsurface data on local geologic structures and the extent at depth of these deposits, the surface outcrops, continuity and estimated reserves of all three deposits indicate that there are more than sufficient quantities of limestone available to supply agricultural requirements during the 10-year period. The proposed mine planning and layout will be the open shelf method of quarrying, the simplest and lowest-cost method, and will be identical for all three operations.

Production and evaluation are examined for four scenarios as follows:

1. Production from the Hoo Doos at the rate of 100,000 tons (76,923 cu. yard) per year supplying all three agricultural areas; Delta, Nenana and Point MacKenzie.
2. Production from the Hoo Doos at the rate of 35,135 tons (27,027 cu. yard) per year for the Delta area only.

3. Production from the Windy Creek at the rate of 40,500 tons (31,154 cu. yard) per year for the Nenana area only.
4. Production from the Kings River at the rate of 24,371 tons (18,747 cu. yard) per year for the Point MacKenzie area only.

Figure 5a shows the three agricultural development areas relative to selected limestone deposits. Results from the above scenarios would provide an insight into and direction towards the optimum method of agricultural limestone production in the state for the first ten years.

MINING

Due to the climatic conditions in Alaska, an 8-hour shift per day, 6 days a week is proposed. Total number of working days per year is 120 and confined within the period May through September.

Besides the differences in production rate and capital investment, which varies with the size of production, the method of mining and conventional crushing on each site is identical. Selected sites are situated near a highway but in non-residential areas with no electricity, water or communications systems, however all three are easily accessible by existing dirt roads.

Quarrying will commence, in each case, on the exposed faces free from overburden, working along the full length (strike) of the outcrop and progressing into the hillsides. Thus, the quarry floor would be a little lower than the adjacent land surface, enhancing easy access into and out of the mining area. Since reserve estimates obtained for the selected deposits by far exceed the requirements for each scenario for the 10-year period under study, it is assumed that exploration work has been completed prior to this study. Hence preproduction costs would be those incurred for support facilities such as office building, warehouse and workshop. Figures 6 and 7 are the hypothetical mine plan and a schematic excavated block diagram respectively.

As very little is known about the geologic structures of these areas and the actual thickness of outcrops below the surface, an open-shelf method of excavation has been recommended; mining in benches would require detailed structural information, which is not available, for slope and pit stability. As this method is the simplest and lowest cost type method, it may further be justified when the lack of skilled labor and high cost of mining in Alaska are taken into consideration.

When state development programs, including the agricultural project, progress, population in these project areas would increase, giving rise to encroaching residential neighbors and more stringent environmental regulations. To avoid such future problems, excavation is done by ripping and dozing with crawler type tractors rather than drilling and blasting. With ripping, vibrations and flying rocks will be nonexisting and dust problems minimized. Furthermore, selected limestone deposits are not too distant from highways, and additional problems could be compounded if motels and restaurants are located on these highways, complementing development programs and increased population. Besides mitigate the foreseeable environmental conflicts, a ripper-dozer combination is very effective in such small scale operations.

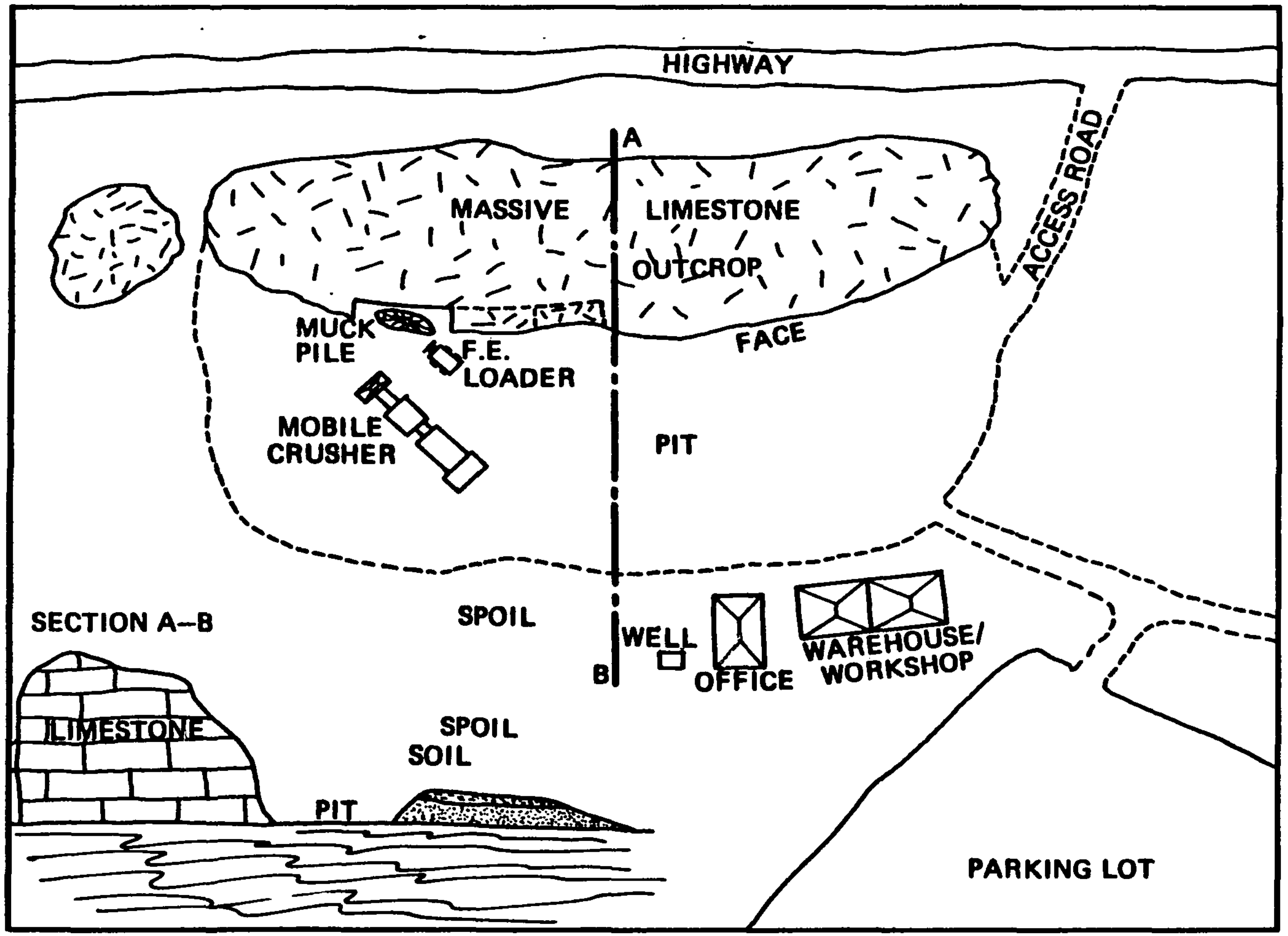

FIGURE 6. HYPOTHETICAL MINE PLAN.

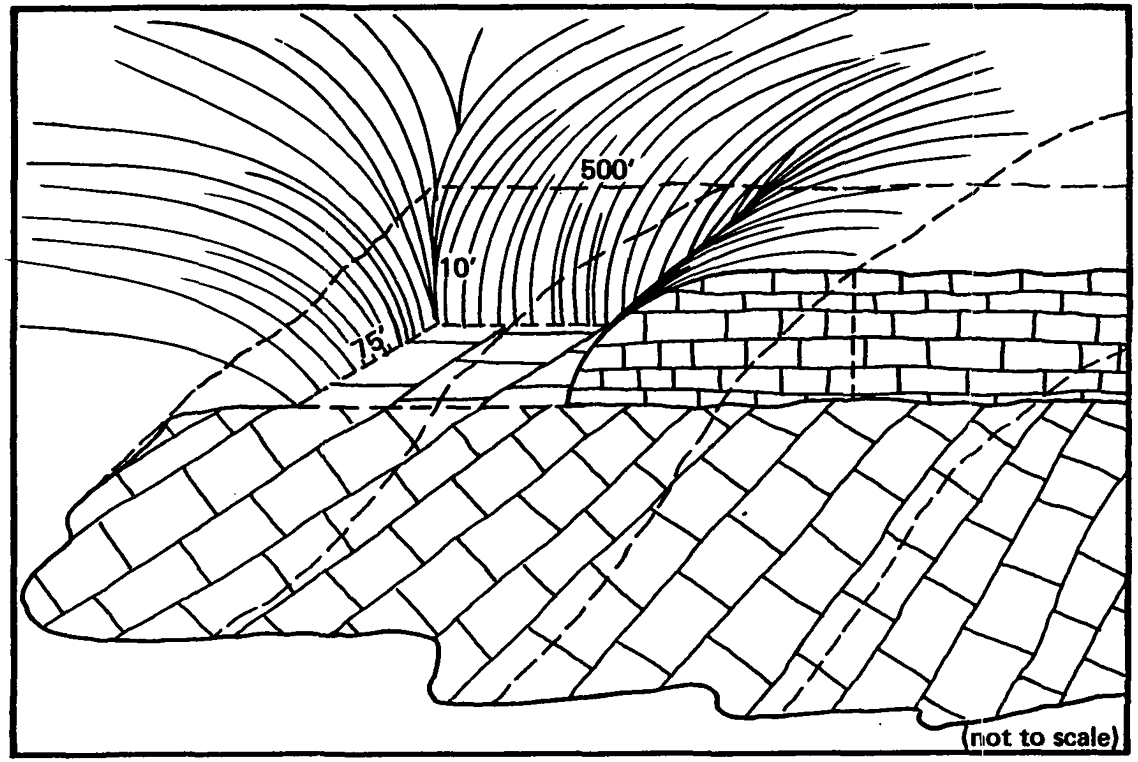

FIGURE 7. SCHEMATIC DIAGRAM

Excavation is done in blocks 10 feet high, 75 feet wide and 500 feet long. Ripper tooth penetration would be maintained at 6 inches and distance between passes at 2 feet. The estimated number of passes per 8 hour day for each scenario for their respective daily production targets would be 35, 12, 14 and 8 (see appendix 2 for calculations). After completing a number of ripping passes, the ripper shank is lifted and the dozer blade lowered to push the ripped material to a point or stock pile on the quarry floor. Transfer of ripped stone to the receiving hopper of a mobile crushing plant in the quarry is done by the load and carry technique using a front end wheel loader.

The front end loader is a high speed loading tool and is indispensable where a high degree of versatility and mobility is required. It can also be occasionally used as a functional crane where heavy plant components may have to be removed for repairs.

The mobile plant is located in the center of the mining block and as near as possible to the working face at the commencement of each block. The advantage here is that the mobile crushing plant does not have to be moved often. Relocation of plant is done after complete excavation of each block and the time period varies from once in 2 months, 6 months, 5 months and 9 months respectively for scenarios 1 to 4 depending on the rate of production. Maximum hauling distance by the front end loader is 261 feet one way.

The size of equipment selected for both ripping and pit haulage as listed below is for optimum economy of production (these equipment selections are for comparison only and are not an endorsement of any particular product or manufacturer).

Scenario 1: 1 Komatsu model D355A-3 (D-9 size) with ripper and U-blade.

1 Terex model 72-61 wheel loader with 6 cu. yd. bucket, counterweight and 29.5 x 25 22 ply (L-4 tires).

Scenarios 2, 3 & 4: 1 each Komatsu model D155A-6 (D-8 size) with ripper and U-blade.

1 each Terex model 72-31B wheel loader with 3 1/4 cu. yd. bucket, counterweight and 23.5 x 25 12 ply (L-3) tires.

Pit arrangement has been designed in such a manner that once the limestone has been ripped from its position in place, it is kept in motion with minimum rehandling and moved the shortest possible distance.

CRUSHING

Crushing limestone for agricultural use is a simple and straightforward process. Processing is done by in-the-quarry crushing method with the use of a mobile crushing plant. The flow sheet is identical for all scenarios, with the exception that two hammermills, which are independently fed, are used in scenario 1 so as to maintain the required throughput. The production rate determines the sizes of various components in the plants.

With the crushing plant located in the quarry and as near to the mining block as possible, the front end loader shuttles back and forth between the muck pile and the open bottom hopper, which is fed at the primary crushing section of the plant. The stone is then transferred by a 4 inch vibrating grizzly feeder into a primary jaw crusher. The crushed material is carried by a discharge conveyor into an ore bin, from which it is belt fed to a 40 x 30 hammermill with 1/4" discharge setting for secondary or final crushing. The output travels to an enclosed 3-deck tower screen with screen sizes 4 inches, 2 inches and 1/8-inch, from which the undersize is conveyed to a conical storage bin as agricultural limestone and the oversize recirculated into the hammermill. The storage bin is fitted with a vibrating mechanism and bottom discharge gates for rapid loading into containers provided by carriers which transport the final product to the various agricultural project areas. A flowsheet of the mobile crushing unit is shown in Figure 8.

Major Plant Components

Pioneer 3042 Jaw Crusher—electrically powered with hopper, vibrating grizzly feeder and discharge conveyor.

Pioneer 4034F Hammermill—electrically powered with belt feeder, hopper and discharge conveyor.

Pioneer 606 Tower Screen (6 ft. x 16 ft.)—electrically powered with feed conveyor. Enclosed for weather and dust protection.

Conveyors (36 ins. x 50 ft.)—4 stationary transfer conveyors with lattice frame. Electrically powered.

Conveyor (36 ins. x 100 ft.)—1 folding, portable stacking conveyor to feed storage facility. Maximum discharge height is 33 ft.

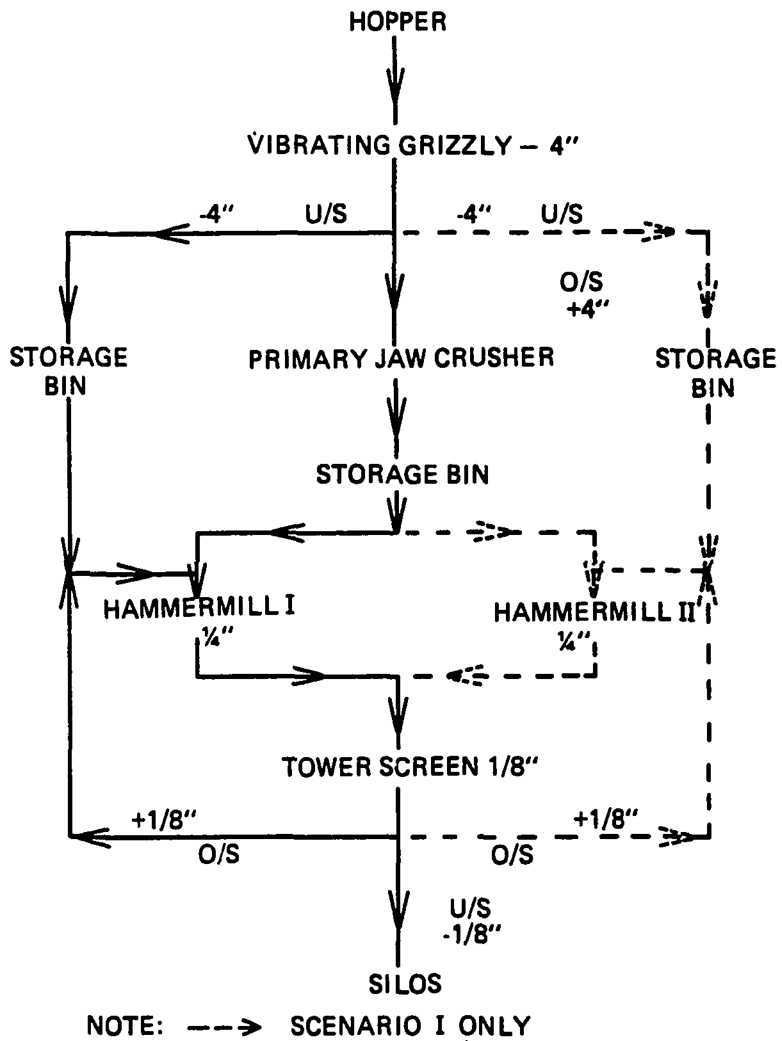

FIGURE 8. FLOW SHEET

Storage bin—provision is made for storage of huge tonnages (minimum capacity, 50% of daily production) of crushed stone. It may be impossible to maintain supply in constant balance with production, due to fluctuations in demand and/or general breakdown.

Generators--1300 kw/hr for plants with two hammermills and 850 kw/hr for plants with one hammermill. (Note: the above equipment selections are for comparison only and are not an endorsement of any particular product or manufacturer).

The jaw crusher is equipped with a vibrating feeder to provide a steady, smooth flow of stone through the crusher. This also prevents choke feeding and minimizes delays.

Hammermills are excellent secondary crushing units for low volume production of agricultural limestone, but must be closed down to 1/8 in. gate bars. Maximum fines can be obtained by operating the hammermill in closed circuit at a low reduction ratio, slow speed and high recirculating loads. Efficiency is not affected until recirculation load exceeds 50%. Wear and tear is minimum if feed contains less than 3% silica.

The mobility of such a crushing plant becomes more significant when a block or a section of the pit is exhausted, for it can be easily moved to another block of the same pit; whereas, any move with a stationary plant is very expensive. It is also easy to follow a receding face with a mobile unit, but a stationary plant has a gradual rise in pit haulage costs as the face moves further away from the plant. Besides performing all the operations of a stationary plant, viz: primary and secondary crushing, screening, etc., it is ideal for small quantities which cannot be handled profitably by a stationary plant on a competitive basis.

Costwise, capital investment per ton of capacity is less, erection costs, delays and difficulties encountered when building a stationary plant are eliminated and investments on road networks are at a minimum. The compactness of the portable plant tends to reduce upkeep expense and thus produces a less expensive product; however, repairs may soar when it has to be moved frequently.

COST DATA AND ECONOMIC ANALYSIS

Cost data

The two elements of the analysis are:

1. Potential earnings or annual generated cash flow of the project.
2. The investment costs necessary to realize such earnings.

Capital requirements are the capital required for mining and beneficiation and includes the equipment required for the mining operations, components of the crushing plant and support facilities. Operating and maintenance costs are cost for items such as wages and fuel that require regular cash outlays so that the mine can function.

Data obtained for these categories are based on quotations from a local market survey on suppliers in Fairbanks and estimation, where necessary. Parameters taken into account for capital cost requirement are briefly discussed below.

Property Acquisition - This is the price paid to an outside party or owner to gain access to, explore and exploit the deposit. This cost is estimated at 2.5% of gross value over the period of operation using a nominal unit value of $70 per ton.

Ripper/Dozer - These are heavy duty machinery equivalent to a D-9 for scenario 1 and a D-8 for scenarios 2 through 4. Their costs are F.O.B. Fairbanks and include rippers and U-blades. Selections are based on the most economic size for the planned production rate.

Front End Loader - Costs again are F.O.B. Fairbanks and include buckets, counterweights and tires. A 6 cu. yd. bucket is recommended for scenario 1 and 3 1/4 cu. yd. bucket for each of the other scenarios.

The above heavy equipment are diesel operated.

Equipment Transportation Cost - Cost is based on quotation received from a local courier for transporting the heavy equipment (dozer, front end loader and crushing plant components) to the various mining sites. These costs are related to the weight, distance from Fairbanks and number of trips. Two trips are anticipated for each mining site. A breakdown of costs is as follows:

TABLE 15: Equipment transportation cost estimates to mine sites in dollars

Item	Windy Creek	Hoo Doos	Kings River
Dozer	1091	1392	2823
Front End Loader	499	701	1924
Crusher	353	512	1543
TOTAL	1943	2605	6290

Generators - Estimates are from quotations provided by a local supplier. Power requirements for the larger plant under scenario 1 is 1300 kw. This requirement would be satisfied by a compact and portable generator composed of 5 small units of 325 kw and 480 volts each. Any 4 of these units will operate at any one time while the fifth remains as a standby.

For the smaller crushing plants 850 kw are required. Generators are similar to the above but have 3 smaller units, each with varying output between 415 to 565 kw and 480 volts with one being as a standby.

An estimation of 60 kw is required for utility services. This is a single portable unit and capable of generating 120/240 volts.

In all cases, the generators are enclosed and made compact for protection against dust and ease of movement. They are diesel operated. See appendices 4 and 4a for power requirements and cost.

Silos - These are conical in shape and provided with vibrators to prevent caking of the finely ground final product and for ease of discharge into haulage trucks. Costs are dependent upon the amount of metal used, which varies directly as its capacity. Cost of support structures range from $1700/ton to $2300/ton and those for bins range from $3200/ton to $3700/ton. A mean cost is used for estimation. Transportation and installation costs are included. They would be locally designed and constructed.

Portable Compressors - In all scenarios, compressors are identical and would be sparsely used, mainly for inflating tires. They are electrically operated and capable of producing a maximum pressure of 100 p.s.i. at 2 cu. ft. per minute with a 2 gallon tank capacity. Power requirement is 1.3 kw., 115 volts running at 3450 revolutions per minute.

Tanks - Sizes of tanks for the various commodities are as specified in Table 3. Cost varies with sizes and includes support structures.

Water Well, Pump and Assembly - Due to the remote location of the mine sites and to eliminate dependency on seasonal fluctuations of source, a well has been recommended. Water provided is primarily for utility purposes. Since no data of the depth of the water table in each site are available, cost estimations of about $50 per foot are based on a maximum depth of 40 feet. Total cost includes transportation to individual sites depending on road condition, pump, overhead tank and installation. Although repair and maintenance costs are nonexisting, the first cost is extremely high, e.g. transportation to site is $90 per mile on the highway and $200 per mile off the highway.

Trucks and Sedans - Costs of support vehicles were obtained locally. Costs shown were the prices quoted at the time of investigation.

Buildings - The warehouse/repair shop (60 ft. x 100 ft) costs about $33 per square foot while the much smaller office/bathroom (20 ft x 60 ft) costs about $42 per square foot. These dimensions are maintained at all sites. Adequate stocks for repair and maintenance must be kept at levels that will minimize down time while awaiting parts. A distant source of supply can add substantially to working capital. Hence the importance of a reasonably large warehouse.

Portable Transceiver - Due to the locations of the selected mining sites together with the remote possibilities of having a telephone system installed in these areas, some system of communication is necessary. Four two-way portable transceivers are recommended for each mining site. The model considered is a 5 watt, 6 channel transceiver covering a radius of about 5 miles. Each cost about $117.

Working Capital - A new mining operation incurs operating expenses from the day of start-up operations. There is a considerable period between start-up and the first payment of the product sold. The funds for this period are called "working capital" and may be estimated on the basis of annual sales or estimated at 10% to 15% of the fixed capital investment. An estimate of 10% of total capital investment which is different from the estimated operating costs, has been used for this study.

Annual Operating Costs

These are the cost for items such as ownership cost of machinery, wages and fuel that require cash outlays to maintain day to day operation of the mine. Operating costs can be estimated in terms of dollars per ton of ore mined. The items in this category have been subdivided into direct, indirect and fixed costs and are briefly discussed below.

Ripper/Dozer - These consitute the most important factors of owning and operating the equipment. The factors considered for the total cost per hour include insurance, general repairs including track repairs, fuel, lubrication and taxes. For an equivalent D-9 and D-8 equipment the costs of $82.08 and $64.06 per hour respectively, provided by suppliers, have been used in the estimation of annual cost.

Front End Loader - The costs of \$58.66 and \$29.84 per hour with 6 cu. yd. and 3 1/4 cu. yd. buckets respectively have been used. Factors considered are the same as for the ripper/dozer with the exception that tire replacement is considered rather than track repairs. Operators' wages are other costs which are estimated separately and not included here.

Plant Maintenance - Plant maintenance costs are a function of the throughput. For the higher capacity plant, as recommended for scenario one only, the cost is \$0.39/ton and that for the smaller plants is \$0.37/ton. From these cost figures, an annual maintenance cost is estimated.

A few used components are available in Fairbanks. These could be purchased at lower prices thereby reducing the capital cost. However, it is generally believed that used equipment will experience higher maintenance and operating costs than similar new equipment. Hence all equipment recommended is new but the latter facts must be weighed against the situation of immediate delivery of used equipment versus many months of delivery of new equipment.

Labor and Supervision - The costs used in this study are based on current union wages being paid in a nonferous metal industry in the State of Alaska. A minimal crew is used consisting of three operators and one maintenance person. It is assumed that the latter would also be a competent driver and that a full time driver would not be necessary. Wage rate is \$4000 per month.

It is also assumed that a manager who is responsible for the overall operation and a supervisor without an assistant could handle quarry and plant operations of the size ranges studied. A supervisor's monthly salary of $4,200 is consistent with current local salaries. See Appendix 5.

Vehicles - At an assumed annual mileage of 10,000 and average gasoline consumption for each of the three vehicles, total cost of gasoline per year is estimated at $2618.5. Average cost of maintenance per year for each vehicle is estimated at $765.8.

Compressor and Water Pump - Power is provided by the utility generator which covers their operating costs. Maintenance for the compressor and pump are negligible.

Depreciation - Depreciation is a deduction from taxable income permitted as a reasonable allowance for the wear and tear or obsolescence of capital assets employed in a businesss. It is a direct function of the capital costs. The straight line method is used throughout. It is assumed that these assets would be fully depreciated, with no salvage value, over the period under consideration. A 10 year life is used for buildings and facilities as well as for the heavy equipment, and a 5 year life for other equipment. See Appendix 6 for depreciation schedule.

Insurance - This is estimated as a percentage (2%) of the capital cost of fixed assets. Heavy equipment and plant are excluded in this estimation, as the cost of insurance is incorporated in the estimation of their operating and ownership costs.

Contingency - These are funds provided to cover the costs of any eventualities which were not taken into account during the planning stage. Fifteen percent of total operating cost is estimated for these funds. See Table 16 and 17.

Economic Analysis

Once the pertinent data have been collected or estimated, a measure of the investment worth is desirable in order to make an unbiased decision as to whether or not to proceed with the project. The discount cash flow technique for evaluating investment projects is used. This method incorporates both the time value of money and cash flow. The rate of return, which is the amount of money an investor needs to earn in order to justify his investment, is then estimated. The following factors are taken into consideration for this estimation:

Gross Revenue

This is the annual gross receipts from sales based on the delivered prices of the final product.

Percentage Depletion

Percentage depletion is a specified percentage of gross income. This amount represents an allowance or annual deduction to compensate for the exhaustion of the deposit in arriving at the income for the taxable year. Fifteen percent depletion allowance is estimated.

Transportation Cost

This is an estimation of the added cost incurred to deliver the final product. As for heavy equipment, delivery of final product will

TABLE 16: Capital requirements and cost estimates

Item / Scenario	1 The Hoo Doos at 833 tons/day $	2 The Hoo Doos at 293 tons/day $	3 Windy Creek at 338 tons/day $	4 Kings River at 203 tons/day $
Acquisition	1,750,000	614,854	708,750	426,484
Ripper/Dozer	378,460	295,320	295,320	295,320
Crushing Plant	985,052	833,052	833,052	833,052
Frong End Loader	239,495	130,780	130,780	130,780
Equipment Transportation	2,605	2,605	1,943	6,290
Generators: Plant	205,300	200,300	200,300	200,300
Utility	18,000	18,000	18,000	18,000
Silos with Vibrator	4,539,850	1,596,850	1,842,100	1,106,350
Portable Compressor (electric, 100 p.s.i.)	319	319	319	319
Tanks: gas (5,000 gals)	2,983	2,983	2,983	2,983
diesel (10,000 gals)	4,788	4,788	4,788	4,788
lube (5,000 gals)	2,983	2,983	2,983	2,983
oil (5,000 gals)	2,983	2,983	2,983	2,983
Water well, pump and assembly	20,000	20,000	20,000	20,000
Trucks: 2 ton maintenance	20,000	20,000	20,000	20,000
3/4 ton pick-up	7,050	7,050	7,050	7,050
Sedan	5,724	5,724	5,724	5,724
Warehouse/Repair shop (60 ft x 100 ft)	200,000	200,000	200,000	200,000
Office/Bathroom (20 ft x 60 ft)	50,000	50,000	50,000	50,000
Portable Transceiver (Walkie Talkie)	470	470	470	470
Total Investment	8,436,062	4,009,061	4,347,545	3,333,876
Working Capital -10% of capital assets	843,606	400,906	434,755	333,388
Contingency -15% of fixed assets	1,265,409	601,359	652,132	500,081
TOTAL CAPITAL REQUIREMENTS	10,545,077	5,011,326	5,434,432	4,167,345
CAPITAL REQUIREMENT/TON	10.55	14.26	13.41	17.10

TABLE 17:

ITEM

DIRECT COST

Ripper/Dozer - operating & ownership
F.E. Loader - operating & ownership
Plant - maintenance
Plant generator - Operating
Maintenance
Operating labor - 12,000 x 4 months
Maintenance labor - 4,000 x 4 months
Supervising labor - 4,200 x 4 months
Vehicles - operating and maintenance
TOTAL DIRECT COST

INDIRECT COST

Administrative & Clerical
6500 x 4 months
Utility generator - Operating
Maintenance
Compressor - operating and maintenance
Water pump - operating and maintenance
TOTAL INDIRECT COST

FIXED COST

*Insurance - 2% of capital cost
TOTAL FIXED COST
SUBTOTAL OPERATING COST
add 15% Contingency
TOTAL OPERATING COST
OPERATING COST/TON

*Heavy equipment and plant excluded

Estimated annual operating cost ($)

SCENARIOS 1	2	3	4
78,797	61,498	61,498	61,498
56,314	28,646	28,646	28,646
39,000	13,000	14,985	9,017
124,800	81,600	81,600	81,600
1,600	1,900	1,900	1,900
48,000	48,000	48,000	48,000
16,000	16,000	16,000	16,000
16,800	16,800	16,800	16,800
4,916	4,916	4,916	4,916
386,227	272,360	274,345	268,377
26,000	26,000	26,000	26,000
5,760	5,760	5,760	5,760
600	600	600	600
30	30	30	30
70	70	70	70
32,460	32,460	32,460	32,460
101,609	42,649	47,554	32,839
101,609	42,649	47,554	32,839
520,296	347,469	354,359	333,676
78,044	52,120	53,154	50,051
598,340	399,589	407,513	383,727
5.98	11.37	10.06	15.75

be contracted to local couriers. Estimates used in the evaluation were obtained from quotations. See Appendix 7.

Tax

Fifty percent corporate tax of taxable income is assumed to cover the various levels of federal, state and local taxes. No "tax holidays" are assumed as this is not a common practice in Alaska.

From the above costs and cash flow estimates, delivered costs have been obtained for a 20% cost of capital: (See Appendices 8 and 8a).

Scenario 1 - $81.26

Scenario 2 - $77.68

Scenario 3 - $78.00

Scenario 4 - $91.24

It should be noted however, that these prices are based on the present estimated agricultural limestone requirements and prices would increase with decrease in demands.

A simulation of cost/benefit to farmers using locally produced crushed limestone for barley production shows positive rates of return for various prices received. Since delivered cost of crushed limestone for scenarios 2 and 3 are approximately equal, cost/benefit simulation for the latter case is not included. See Appendix 9.

SUMMARY/RECOMMENDATIONS

1. The value of agricultural limestone as an essential crop production tool with the capability to increase not only crop growth and yield, but income as well, has been well demonstrated from various examples.

2. There is a need to re-emphasize the economic returns possible with proper application of agricultural limestone. Results or recommendations from experimental work under local conditions should be used to determine if it is correct in Alaska.

3. Authorities (Cooperative Extension Service, Agricultural Experimental Station, Agricultural Action Council, State Development and Economic Planners) should commence an educational process well in advance of lime utilization, by attending consumers meetings and use some few minutes in their program to talk about agricultural limestone. Agricultural limestone literature should be distributed at these meetings where possible.

The need for agricultural limestone in acid soils should be emphasized at every opportunity, by making effective use of the media in advance of the spreading season. Farmers should be reminded, as often as possible, of the harmful effects of soil acidity on soil productivity, fertilizer efficiency, herbicide effectiveness and farm income. Its benefits should be stressed.

4. In the case of leases, authorities as well as farmers should ensure favorable and reasonable land owner-renter contracts. Short-term lease contracts discourage the use of slow-acting crop production items, such

as agricultural limestone, by renters who would like to see a return on every dollar spent. Increased contract period and terms favoring more equitable sharing of costs between land owner and renter can enhance the use of agricultural limestone at all times, irrespective of ownership.

5. Finally, to would be aglime producers and/or vendors they will be performing a valuable service to farmers. Their product is a product of value to production agriculture and should be sold on that basis.

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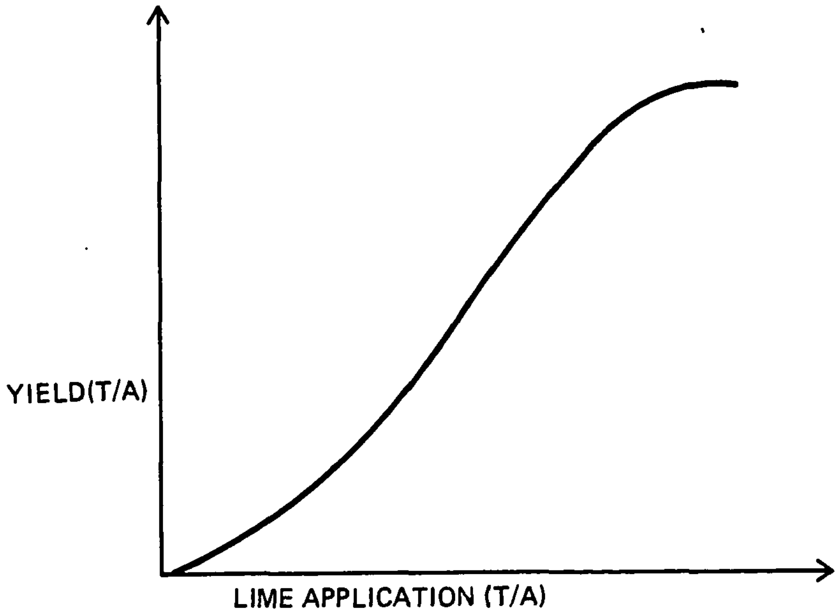
APPENDIX 1



GRAPHICAL REPRESENTATION OF THE LAW OF DIMINISHING RETURNS

APPENDIX 2 (a)

Existing Agricultural Land and State Land Transfer Schedule (Acres)

	1975*	1978-1982	NEW LAND** 1983-1985	1985-1992+	Total++
Matanuska Valley	12,140				148,140
Point MacKenzie		15,000			
Fish Creek			21,000		
Susitna				100,000	
Tanana Valley	5,865				362,865
Delta I		60,000			
Delta II		25,000			
Nenana-Tolchaket			150,000		
Delta Creek			40,000		
Kantishna				75,000	
Yukon Valley					100,000
Yukon Flats				100,000	
Kenai	2,170				2,170
Southwest	150				150
Non-Project Land		30,000	48,000	25,000	103,000
STATE TOTAL	20,325	130,000	259,000	300,000	709,325

* Acreage existing prior to state agricultural disposals.

** Gross project acreage.

\+ These are preliminary and subject to revision following detailed soil surveys and final land ownership designations.

++ Total by region—includes existing and proposed agricultural land.

Source: Ten year plan for Alaska Agricultural Development, Alaska Agricultural Action Council, Dept. of Commerce and Economic Development, State of Alaska, 1982.

APPENDIX 2 (b)

SCHEDULE OF LAND CLEARED BY PROJECT (ACRES)

YEAR	Delta II	Point MacKenzie	Nenana I	Nenana II	Nenana III	Delta Creek	Fish Creek	TOTAL
1983	7,500	3,900	—	—	—	—	—	11,400
1984	7,500	3,900	15,000	—	—	—	—	26,400
1985	7,500	3,900	15,000	15,000	—	12,000	4,600	58,000
1986	—	—	15,000	15,000	15,000	12,000	4,600	61,600
1987	—	—	—	15,000	15,000	12,000	4,600	46,600
1988	—	—	—	—	15,000	—	—	15,000
TOTAL	22,500	11,700	45,000	45,000	45,000	36,000	13,800	219,000

Source: Ten year plan for Alaska Agricultural Development, Alaska Agricultural Action Council, Dept. of Commerce and Economic Development, State of Alaska, 1982.

APPENDIX 2 (c)

REQUIRED CROP PRODUCTION BY PROJECT** (ACRES)

YEAR	Delta II	Point MacKenzie	Nenana* I	Nenana* II	Nenana* III	Delta* Creek	Fish Creek	TOTAL
1983	—	—	—	—	—	—	—	—
1984	—	—	—	—	—	—	—	—
1985	—	4,700	—	—	—	—	—	4,700
1986	10,100	4,700	—	—	—	—	—	14,800
1987	13,600	4,700	22,500	—	—	—	—	40,800
1988	13,600	8,900	30,100	22,500	—	27,000	6,900	109,000
1989	13,600	8,900	30,100	30,100	22,500	36,100	9,200	150,500
1990	13,600	8,900	30,100	30,100	30,100	36,100	9,200	158,100

* Contractual acreage estimated.

** Actual contractual requirements - actual acreage may be higher.

Source: Ten year plan for Alaska Agricultural Development, Alaska Agricultural Action Council, Dept. of Commerce and Economic Development, State of Alaska, 1982.

APPENDIX 3

ESTIMATED RIPPER PRODUCTION (Theoretical)

Length of block = 500 ft.
Distance between passes = 2 ft.
Ripping or penetration depth = 6 ins.

Volume of rocks ripped per pass = $\frac{500 \times 2 \times 0.5}{27}$ cu. yd.

= $\frac{500}{27}$ - 18.5 cu. yd. or 24 tons

Number of passes per day for Scenario 1 = $\frac{641}{18.5}$ = 35

Number of passes per day for Scenario 2 = $\frac{225.5}{18.5}$ = 12

Number of passes per day for Scenario 3 = $\frac{259.6}{18.5}$ = 14

Number of passes per day for Scenario 4 = $\frac{156.22}{18.5}$ = 8

APPENDIX 4

POWER REQUIREMENTS AND COST

Scenario 1

Plant: generator	1300 kw x 8 hr/day = 10400 kw hr/day x 120 days/yr = kw hr/yr	1,248,000
Utility: generator	60 kw x 8 hr/day = 480 kw hr/day x 120 days/yr = kw hr/yr	57,600
TOTAL (kw hr/yr)		1,305,600

Requirements: 1,305,600 kw hr/yr ÷ 960 hrs/yr = 1360 kw Say 1.5 MW

Fuel: 1,305,600 kw hr/yr ÷ 10 kw hr/gal 130,560 gal/yr.

Operating cost (fuel only): 130,560 gal/yr x \$1.00/gal = \$130,560/yr

Maintenance:	Plant generator @ \$400/month x 4 months =	\$ 1,600/yr
	Utility generator @ \$150/month x 4 months =	600/yr
		\$ 2,200/yr

Cost of power = \$(130,560 + 2,200)/yr ÷ 1,305,000 kw hr/yr = \$0.10/kw hr

Scenario 2, 3 & 4:

Plant: generator	850 kw x 8 hr/day = 6800 kw hr/day x 120 days/yr = kw hr/yr	816,000
Utility: generator	60 kw x 8 hr/day = 480 kw hr/day x 120 days/yr = kw hr/yr	57,600
TOTAL (kw hr/yr)		873,600

Requirement: 873,600 kw hr/yr ÷ 960 hrs/yr = 910 kw say 1 MW

Fuel: 873,600 kw hr/yr ÷ 10 kw hr/gal 87,360 gal/yr

Operating cost (fuel only): 87,360 gal/yr x \$1.00/gal = \$87,360/yr

Maintenance:	Plant generator @ \$475/month x 4 months =	\$ 1,900/yr
	Utility generator @ \$150/month x 4 months =	600/yr
		\$ 2,500/yr

Cost of power = \$(87,360 + 2,500)/yr ÷ 873,000 kw hr/yr = \$0.10/kw hr

APPENDIX 4 (a)

SUMMARY - POWER REQUIREMENTS AND COST

Yearly	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Operating cost (fuel) - $	130,560	87,360	87,360	87,360
Maintenance - $	2,200	2,500	2,500	2,500
Requirement - MW	1.5	1	1	1
Cost/kw hr - $	0.10	0.10	0.10	0.10

APPENDIX 5

PERSONNEL REQUIREMENTS - SALARY & WAGES

FOR ALL SCENARIOS

Number	Designation	Monthly Salary ($)
1	Manager	4,500
1	Supervisor (Quarry & Plant)	4,200
1	Secretary	2,000
1	Plant Operator	4,000
1	Ripper/Dozer Operator	4,000
1	F/E Loader Operator	4,000
1	Maintenance	4,000

APPENDIX 6

DEPRECIATION SCHEDULE

Item	Years Straight-line dep.	Initial Cost Scenario 1	Initial Cost Scenario 2	Initial Cost Scenario 3	Initial Cost Scenario 4	Annual Depreciation Allowance Scenario 1	Annual Depreciation Allowance Scenario 2	Annual Depreciation Allowance Scenario 3	Annual Depreciation Allowance Scenario 4
Buildings & Facilities	10	250,000	250,000	250,000	250,000	25,000	25,000	25,000	25,000
Long Life Equipment	10	6,382,499	3,090,644	3,335,232	2,603,829	638,250	309,064	333,523	260,383
Short Life Equipment	5	53,563	53,563	53,563	53,563	10,713	10,713	10,713	10,713
TOTAL						673,963	344,777	369,236	296,096

APPENDIX 7

TRANSPORTATION COST ESTIMATES - FINAL PRODUCT

	DESTINATION (Agricultural Area)					
	Delta		Nenana		Point MacKenzie	
Selected Deposits	Cost/ton ($)	Annual Cost ($)	Cost/ton ($)	Annual Cost ($)	Cost/ton ($)	Annual Cost ($)
Hoo Doos	20.60	723,771	51.20	2,073,600	68.00	1,657,194
Windy Creek	—	—	25.60	1,036,800	—	—
Kings River	—	—	—	—	20.80	506,906

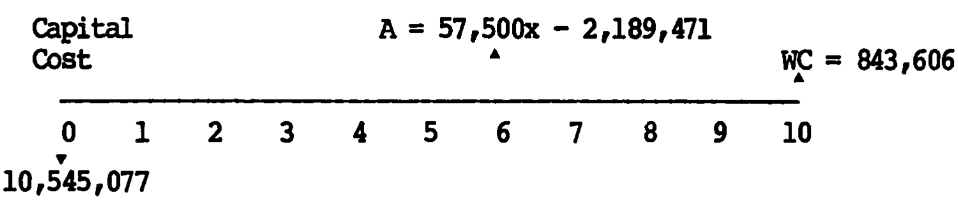
APPENDIX 8

LANDED COST ESTIMATION AT 20% RATE OF RETURN

Scenario 1:

Let the selling price per ton be represented by "$x"

	$
Gross Income	100,000x
Transportation Cost	4,454,565
Depreciation	673,963
Operating Cost	598,340
Taxable before Depletion	100,000x - 5,726,868
15% Depletion	15,000x
Taxable Income	85,000x - 5,726,868
Tax at 50%	42,500x - 2,863,434
Net Profit	42,500x - 2,863,434
+ Depreciation	673,963
+ Depletion	15,000x
Annual Cash Flow	57,500x - 2,189,471



$$10{,}545{,}077 = (57{,}500x - 2{,}189{,}471)\,(P/A_{20,10}) + 843{,}606\,(P/F_{20,10})$$

$$= 241{,}040x - 9{,}178{,}262.4 + 136{,}242.37$$

$$x = \$81.26$$

APPENDIX 8 (continued)

LANDED COST ESTIMATION AT 20% RATE OF RETURN

Scenario 2:

Let the selling price per ton be represented by "$x"

	$
Gross Income	35,134.5x
Transportation Cost	723,770.70
Depreciation	344,777
Operating Cost	399,589
Taxable before Depletion	35,134.5x - 1,468,136.7
15% Depletion	5,270x
Taxable Income	29,865x - 1,468,136.7
Tax at 50%	14,933x - 734,068.35
Net Profit	14,933x - 734,068.35
+ Depreciation	344,777
+ Depletion	5,270x
Annual Cash Flow	20,203x - 389,291.35

Capital Cost

A = 20,203x - 389,291.35

WC = 400,906

0 1 2 3 4 5 6 7 8 9 10

5,011,326

$$5{,}011{,}326 = (20{,}203x - 389{,}291.35)\ (P/A_{20,10}) + 400{,}906\ (P/F_{20,10})$$

$$= 84{,}688.5x - 163{,}190.93 + 64{,}746.3$$

$$x = \$77.68$$

APPENDIX 8 (continued)

LANDED COST ESTIMATION AT 20% RATE OF RETURN

Scenario 3:

Let the selling price per ton be represented by "$x"

	$
Gross Income	40,500x
Transportation Cost	1,036,800
Depreciation	369,236
Operating Cost	407,513
Taxable before Depletion	40,500x - 1,813,549
15% Depletion	6,075x
Taxable Income	34,425x - 1,813,549
Tax at 50%	17,213x - 906,774.5
Net Profit	17,213x - 906,774.5
+ Depreciation	369,236
+ Depletion	6,075x
Annual Cash Flow	23,288x - 537,538.5

Capital Cost

A = 23,288x - 537,538.5

WC = 434,755

0 1 2 3 4 5 6 7 8 9 10

5,434,432

$$5{,}434{,}432 = (23{,}288x - 537{,}538.5)\ (P/A_{20,10}) + 434{,}755\ (P/F_{20,10})$$

$$= 97{,}621.2x - 2{,}253{,}361.4 + 70{,}213$$

$$x = \$78.00$$

APPENDIX 8 (continued)

LANDED COST ESTIMATION AT 20% RATE OF RETURN

Scenario 4:

Let the selling price per ton be represented by "$x"

	$
Gross Income	24,371x
Transportation Cost	506,906
Depreciation	296,096
Operating Cost	383,727
Taxable before Depletion	24,371x - 1,564,569
15% Depletion	3,656x
Taxable Income	20,715x - 1,186,729
Tax at 50%	10,358x - 593,364.5
Net Profit	10,358x - 593,364.5
+ Depreciation	296,096
+ Depletion	3,656x
Annual Cash Flow	14,014x - 297,268.5

Capital Cost

A = 14,014x - 297,268.5

WC = 333,388

0 1 2 3 4 5 6 7 8 9 10

4,167,345

$$4{,}167{,}345 = (14{,}014x - 297{,}268.5)\ (P/A_{20,10}) + 333{,}388\ (P/F_{20,10})$$

$$= 58{,}747x - 1{,}246{,}149.6 + 53{,}842.2$$

$$x = \$91.24$$

APPENDIX 8 (a)

ESTIMATION OF ANNUAL CASH FLOW AND DCFROR ON INVESTMENT

Scenario 1: 100,000 tons per year at $81.26/ton

	$
Gross Income	8,126,000
Transportation Cost	4,454,565
Depreciation	673,963
Operating Cost	598,340
Taxable before Depletion	2,399,132
50% Limit	1,199,566
15% Depletion	1,218,900
Taxable Income	1,199,566
Tax at 50%	599,783
Net Profit	599,783
+ Depreciation	673,963
+ Depletion	1,199,566
Cash Flow	2,473,312

$$10{,}545{,}077 = 2{,}473{,}312\ (P/A_{i,10}) + 843{,}606\ (P/F_{i,10})$$

$$i = 19.92\%$$

APPENDIX 8 (a) (continued)

ESTIMATION OF ANNUAL CASH FLOW AND DCFROR ON INVESTMENT

Scenario 2: 35,134.5 tons per year at $77.68/ton

	$
Gross Income	2,729,248
Transportation Cost	723,770.7
Depreciation	344,777
Operating Cost	399,589
Taxable before Depletion	1,261,111.3
50% Limit	630,555.65
15% Depletion	409,387.2
Taxable Income	851,724.1
Tax at 50%	425,862.05
Net Profit	425,826.05
+ Depreciation	344,777
+ Depletion	409,387.2
Cash Flow	1,180,026.3

$$5{,}011{,}326 = 1{,}180{,}026.3\ (P/A_{i,10}) + 400{,}906\ (P/F_{i,10})$$

$$i = 20.001\%$$

APPENDIX 8 (a) (continued)

ESTIMATION OF ANNUAL CASH FLOW AND DCFROR ON INVESTMENT

Scenario 3: 40,000 tons per year at $78.00/ton

	$
Gross Income	3,159,000
Transportation Cost	1,036,800
Depreciation	369,236
Operating Cost	407,513
Taxable before Depletion	1,345,451
50% Limit	672,725.5
15% Depletion	473,850
Taxable Income	871,601
Tax at 50%	435,800.5
Net Profit	435,800.5
+ Depreciation	369,236
+ Depletion	473,850
Cash Flow	1,278,886.5

$$5{,}434{,}432 = 1{,}278{,}886.5\ (P/A_{i,10}) + 434{,}755\ (P/F_{i,10})$$

$i = 19.99\%$

APPENDIX 8 (a) (continued)

ESTIMATION OF ANNUAL CASH FLOW AND DCFROR ON INVESTMENT

Scenario 4: 24,370.5 tons per year at \$91.24/ton

	\$
Gross Income	2,223,564.4
Transportation Cost	506,906
Depreciation	296,096
Operating Cost	383,727
Taxable before Depletion	1,036,835.4
50% Limit	518,417.7
15% Depletion	333,534.7
Taxable Income	703,300.7
Tax at 50%	351,650.35
Net Profit	351,650.35
+ Depreciation	296,096
+ Depletion	333,534.7
Cash Flow	981,281.05

$$4{,}167{,}347 = 981{,}281.05\ (P/A_{i,10}) + 333{,}388\ (P/F_{i,10})$$

$i = 19.99\%$

APPENDIX 9

SIMULATION OF COST/BENEFIT FOR BARLEY PRODUCTION

Scenario 1: Cost of aglime at $81.26/ton

(a) Price of barley at $100/ton

Yield Increase	Value of Increased Yield	Cost of Aglime (5 yr period)	Annual Cost of Aglime	Added Return per $ Spent on Aglime
(T/A)	($/A)	($/A)	($/A)	(%)
0.50	50.00	162.52	32.50	54
1.00	100.00	162.52	32.50	208
1.25	125.00	162.52	32.50	285

(b) Price of barley at $125/ton

0.50	62.50	162.52	32.50	092
1.00	125.00	162.52	32.50	285
1.25	156.25	162.52	32.50	380

(c) Price of barley at $150/ton

0.50	75.00	162.52	32.50	131
1.00	150.00	162.52	32.50	362
1.25	187.50	162.52	32.50	477

APPENDIX 9 (continued)

Scenario 2: Cost of aglime at $77.68/ton

(a) Price of barley at $100/ton

Yield Increase	Value of Increased Yield	Cost of Aglime (5 yr period)	Annual Cost of Aglime	Added Return per $ Spent on Aglime
(T/A)	($/A)	($/A)	($/A)	(%)
0.50	50.00	155.36	31.07	060
1.00	100.00	155.36	31.07	222
1.25	125.00	155.36	31.07	302

(b) Price of barley at $125/ton

0.50	62.50	155.36	31.07	101
1.00	125.00	155.36	31.07	302
1.25	156.25	155.36	31.07	403

(c) Price of barley at $150/ton

0.50	75.00	155.36	31.07	141
1.00	150.00	155.36	31.07	383
1.25	187.50	155.36	31.07	503

APPENDIX 9 (continued)

Scenario 4: Cost of aglime at $91.24/ton

(a) Price of barley at $100/ton

Yield Increase	Value of Increased Yield	Cost of Aglime (5 yr period)	Annual Cost of Aglime	Added Return per $ Spent on Aglime
(T/A)	($/A)	($/A)	($/A)	(%)
0.50	50.00	182.48	36.50	037
1.00	100.00	182.48	36.50	174
1.25	125.00	182.48	36.50	242

(b) Price of barley at $125/ton

0.50	62.50	182.48	36.50	071
1.00	125.00	182.48	36.50	242
1.25	156.25	182.48	36.50	328

(c) Price of barley at $150/ton

0.50	75.00	182.48	36.50	105
1.00	150.00	182.48	36.50	311
1.25	187.50	182.48	36.50	414

APPENDIX 10

OTHER POTENTIAL USES FOR LIMESTONE
(Lamar, 1961)

Alaska is a developing state and endowed with abundant limestone deposits—enumerated and discussed earlier. This section is therefore incorporated to discuss briefly many other potential uses and their specifications of crushed limestone considered to be of vital importance to the future industrial and economic development and planning of the state. In the absence of this section, the report could be considered incomplete. The importance of this statement would become more apparent as these various uses are discussed.

1. Aggregate and Road Stone

Crushed limestone is used as aggregate in portland cement concrete for roads, buildings and other structures in combination with bituminous materials for roads and similar constructions. It is also used to make base courses for various types of pavements and waterbound maca-dam.

Aggregate may be coarse or fine. Coarse aggregate is defined as one predominantly retained on No. 4 sieve, whereas fine aggregate will pass a 3/8-inch sieve. The fine aggregate produced by crushing limestone is sometimes referred to as stone screening or stone sand. The maximum allowable amount of clay is 1% in fine aggregate portland cement concrete, 0.25% in coarse aggregate and should be free of chert, flint, limonite and shale and other materials whose disintegration is accompanied by an increase in volume which may cause spalling of concrete—important in construction and road building.

2. Barnstone

Crushed limestone referred to as barnstone or barn lime is sprinkled on the floors and walls of stock barns, especially dairy barns, where it serves as a neutralizing agent and absorbent of organic wastes. It also gives a clean appearance. There are no specifications for barnstone. A white or light colored stone of reasonably high purity is desirable. Finely ground stones are reported to have been used for this purpose—important to agriculture.

3. Copper Purification

The sale and use of limestone for the purification of copper is also reported. It is probably used as a flux or as a lime in the refining process, particularly as a slag forming material in the electrothermic refining of copper—important to the mineral industry for the establishment of an in-state metal refinery industry.

4. Fertilizer Filler

Limestone is used as a filler for fertilizers to add weight, reduce caking, improve the physical condition of the mixture and to adjust the mixture to the desired ratio of the fertilizing elements. It also reduces or eliminates the acidity of fertilizers. A reasonably pure limestone pass through No. 8 to No. 20 sieve sizes is required—important to agriculture.

5. Filter Stone

Crushed limestone is used in sewage disposal plants to form the beds of trickling filters over which the liquid portion of the sewage is sprayed. The rock serves as a host for organisms which purify the sewage. Filter stone is used in two sizes; 3 1/2" x 2 1/2" and 3" x 1 1/2". Careful grading is required together with close limitations on the amount of fines. Siliceous impurities are not objectionable if they are fine grained, but pyrite, marcasite or clay should be avoided. Some types of chert are undesirable, particularly if used in the upper part of the filter bed.

Filter stone should have a rough surface to provide anchorage for bacteria and other organisms. Limestone and dolomite are competitive with granite and quartzite as filter stones--important for utility sources.

6. Flux

Again, where an in-state metal refinery is eminent, limestone and dolomite could be used as fluxes in the smelting of metalliferous ores to form a fluid slag with impurities such as silica and alumina.

7. Glass

Limestone or dolomite in the raw state, or burned to lime is an important constituent of the "batch" for which glass is made. Some glass batches contain 20 to 30% of limestone or dolomite.

Limestone should have uniform composition and high purity. The calcium carbonate constituent of the limestone should exceed 98%. Iron oxide should not exceed 0.05% and preferably less than 0.02%. Another specification permits a maximum of 0.3% iron for most glass and 0.03% for flint glass. A low sulphur and phosphorous content is a requisite and carbon should be kept to a minimum.

The 1959 British standard, which may not be applicable in the United States, for limestone for the manufacturing of colorless glasses requires that calcium oxide should not be less than 52%, i.e., 98% calcium carbonate and total iron as ferric oxide not more than 0.035%.

The limestone or dolomite should be crushed to pass a 16- or 20-mesh sieve and should be largely coarser than 100 or 140 mesh—important for industrial development.

8. Lime

Lime is made from limestone or dolomite by burning them so as to drive off carbon dioxide. Limestone yields a product consisting mainly of calcium oxide (CaO) whereas the product from dolomite is mainly calcium and magnesium oxides.

The bulk of the commercial lime in the United States consists of calcium oxide and between 0 and 45% magnesium oxide and less than 5% silica, alumina, iron oxide and other impurities. There are three kinds of lime:

1. High calcium lime contains not less than 90% calcium oxide and 0 to 5% magnesium oxide.
2. Dolomitic or high magnesium lime contains 25 to 45% magnesium oxide.
3. Low magnesium lime contains 5 to 25% magnesium oxide.

The first two are the most widely used in the United States. Some limes have the property of settling under water and are made from limestone containing sufficient argillaceous or siliceous matter. No specifications for the maximum amount allowable of these in the limestone are given.

Most high calcium limes are made from limestones containing less than 3% impurities, less than 5% magnesium carbonate and between 95 to 98% calcium carbonate. Similarly high limes are made from dolomites containing less than 3% impurities and more than 40% magnesium carbonate. Limestone or dolomite used to produce lime should be sufficiently hard so that there is little production of fines (or dust) during burning. Where the limestone or dolomite decrepitate when heated, this increases the amount of dust and makes it unsuitable. High calcium limes are more expensive for use in acid soils but of interest to the agricultural sector.

9. Portland Cement

Limestone is the major material used for the manufacturing of portland cement. It constitutes about 75 to 80% by weight of the raw material. The raw materials are finely ground, blended in carefully proportioned amounts and burned in a kiln. A clinker is formed which is finely ground with the addition of a small amount of gypsum (5%) to yield portland cement.

Limestone used should contain more than 75% calcium carbonate and less than 3% magnesia. Sulphur should be low and iron oxide less than 0.01%. Chert nodules, other hard materials or coarse quartz grains are undesirable, as they require more than normal grinding to reduce them to the required fineness or powder. Portland cement is of particular interest to the construction and building industries in all phases of development.

10. Masonry Cement

This is prepared by intergrinding portland cement clinker or finished portland cement with limestone to a fineness greater than that of portland cement.

11. Mineral Feeds for Limestone

Pulverized limestone is used as a source of calcium in mineral feeds for limestone.

A high calcium limestone containing more than 95% calcium carbonate is generally recommended. The fluorine content should be very low (0.03%) as fluorine from rock phosphate or sodium fluoride was found harmful to swine. Smaller amounts of fluorine had been found detrimental to dairy animals. Stone ground to pass 200-mesh or finer, is used.

12. Poultry Grit

Limestone is fed to poultry as a source of calcium for the formation of egg shells and bones. It also serves as a grit or grinding agent in the gizzard. In this case, fluorine content should not exceed 0.1%. Larger amounts may be harmful.

Limestone for poultry grit should pass a 4 or 6-mesh sieve and be retained on a 10-mesh sieve. The grit is graded into turkey, chicken, poultry or bird grit.

13. Rip rap

Rip rap consists of large blocks of stone used for foundations and for filling around the base of structures subject to erosion, such as the base of piers, abutments, etc. It could also be used on the banks of streams or shores of lakes to prevent erosion. There are no general specifications for rip rap. However, a weather resistant stone free from cracks and laminations which will cause it to split is desirable. Pyrite veinlets, clay partings or chert are undesirable. A requirement in some states is that no stone be less than 6" in its smallest dimension.

14. Rock Dusting

Limestone dust is applied to the walls, roofs and floors of underground coal mines to prevent or minimize coal dust explosions. The dust should be light colored and to comply with "American Standard Practice for Rock Industry Underground Bituminous Coal and Lignite Mines to Prevent Coal-Dust Explosions:, it should be:

(a) a material 100% of which will pass through a United States No. 20 sieve and 70% or more should pass through a No. 200 sieve.

(b) a material of which when wetted and dried will not cohere or form a cake dust.

(c) A material that does not contain more than 5% of combustible matter or more than a total of 5% of free and combined silica.

Limestone and similar carbonates produce the best rock dust as they have a low silica content, little tendency to cake and a light color that aids illumination. With the development of coal industry in the state, some by underground methods, rock dusting using limestone may be of great importance.

15. Water Treatment

Limestone is used as a coagulent or stabilizer to prevent after precipitation of calcium carbonate from lime-softened water. Municipal water works may also use crystalline high calcium limestone.

Suggested size specifications vary. Pulverized, finely ground limestone between 150 and 325-mesh and limestone ground so that 90% will pass a 100-mesh sieve and the remainder a 60-mesh sieve are suggested sizes. This important use, particularly to a developing state like Alaska, is obvious.

16. Dust Suppressant in Unpaved Roads and De-icing

Limestone can be used to produce calcium and magnesium acetate (CMA) by simple dissolution of limestone in acetic acid. This product can replace sodium and calcium chlorides which have been used for many years for de-icing roads and airport runways in the winter months. The latter have adverse environmental effects and produce corrosion problems. CMA has very good de-icing characteristics and are not corrosive or harmful to the environment.

The abundance of limestone deposits in the State of Alaska and natural gas which can be converted to acetic acid would make local production economically feasible in the state. CMA is effective when used in unpaved roads to reduce dust generated by vehicles in summer. CMA manufacture could become a significant industry in Alaska in the future.

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